# GEOLOGY OF BIG PORCUPINE, CLEAR, CROWN, NUNIKANI AND SHERBORNE CATCHMENTS (HALIBURTON COUNTY)

R.A.Reid and W.R. Snyder

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# GEOLOGY OF BIG PROCUPINE, CLEAR, CROWN, NUNIKANI AND SHERBORNE CATCHMENTS (HALIBURTON COUNTY)

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## PREFACE

The unpublished Data Report Series is intended as a readily available source of basic data collected for lakes and watersheds in the Muskoka-Haliburton area of Ontario. These data were collected as part of the Lakeshore Capacity Study and/or the Acid Precipitation in Ontario Study.

The limnological portion of the Lakeshore Capacity Study (1975-81) was initiated to investigate the relationships between lakeshore development and lake trophic status in low ionic strength Precambrian lakes. The Acid Precipitation in Ontario Study (1979-present) was initiated, in part, to investigate the effects of the deposition of strong acids on aquatic and terrestrial ecosystems in Ontario. The primary findings of these studies have been and will continue to be published as reviewed papers and technical reports.

# ABSTRACT

This report discusses the bedrock and surficial geology of five catchments in Haliburton County. The geological history of the area, the regional bedrock geology, and the surficial geology of the study sites are presented. The areal extent of each bedrock and surficial type in each of the subwatersheds of the five catchments is reported.

TABLE OF CONTENTS

LIST OF TABLES

## LIST OF FIGURES

Figure



APPENDIX 2

## 1. INTRODUCTION

This report describes the bedrock and surficial geology of the Big Porcupine, Clear, Crown, Nunikani and Sherborne catchments. The glacial history of the Algonquin-Haliburton area is also described. The report also includes stream water chemistry data with some discussion relative to the geological information.

FIG. 1: Location of the five watersheds

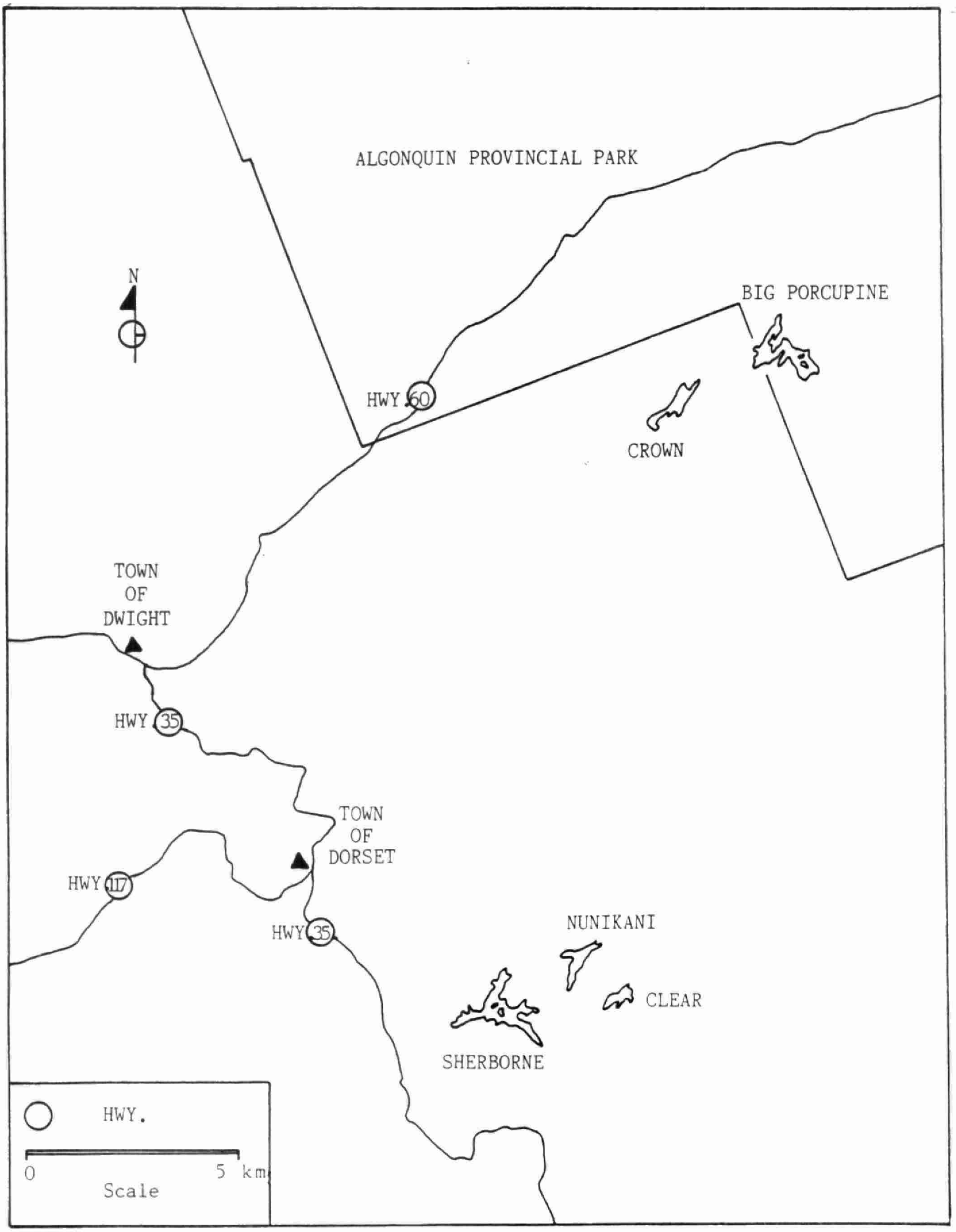


Table 1: Watershed location and areas

| Parameter | Big Porcupine | Clear | Crown | Nunikani | Sherborne |
|---|---|---|---|---|---|
| Latitude (°N) | 45°27' | 45°11' | 45°26' | 45°12' | 45°11' |
| Longitude (°W) | 78°37' | 78°43' | 78°40' | 78°44' | 78°47' |
| Township | Lawrence-Livingstone | Sherborne | Livingstone | Sherborne | Sherborne |
| | | | Areas ($km^2$) | | |
| Lake | 2.39 | 0.90 | 1.38 | 1.11 | 2.49 |
| Islands | 0.097 | | 0.018 | 0.006 | 0.25 |
| Watershed | 20.90 | 1.46 | 3.63 | 6.77 | 16.22 |
| Subwatersheds: | | | | | |
| 1 | 0.84 | | 0.48 | 0.24 | 0.08 |
| 2 | 0.23 | | 0.22 | 0.20 | 0.07 |
| 3 | 4.01 | | 0.30 | 0.16 | 2.38 |
| 4 | 1.12 | | 0.11 | 2.14 | 0.43 |
| 5 | 10.65 | | 0.12 | 0.35 | 0.29 |
| 6 | 0.81 | | 0.17 | 0.81 | 4.30 |
| 7 | | | | 0.68 | 0.89 |
| 8 | | | | 0.05 | 0.12 |
| 9 | | | | 0.05 | 0.38 |
| 10 | | | | 0.50 | 1.64 |
| 11 | | | | | 0.36 |
| 12 | | | | | 0.17 |
| 13 | | | | | 0.24 |
| 14 | | | | | 0.12 |
| Ungauged | 3.24 | | 2.23 | 1.62 | 4.76 |

## 3. DRAINAGE NETWORK

### Big Porcupine Lake

Big Porcupine is a second order lake whose catchment contains Ling Lake, Tea Lake and several large ponds. Inflows generally follow glacially scoured faults and exhibit an angular drainage pattern. The streams in subwatershed #5 are an exception in that they meander in the large peat/outwash complex valley.

Big Porcupine drains to the north into Ragged Lake, which drains into Smoke Lake. The Smoke Lake outflow joins the Oxtongue River, Lake of Bays, Muskoka, and Moon River to Lake Huron.

### Clear Lake

Clear Lake is a true headwater lake with no ponds in its watershed. Clear Lake's watershed has only ephemeral streams and none of the basin boundary is greater than 0.4 km from the lake. The Clear Lake outflow enters the east arm of Big Hawk Lake which flows southward to Halls Lake. Halls Lake flows through many lakes including Boshkung, Mountain and Horseshoe, en route to the Gull River. The Gull River eventually reaches Lake Simcoe and then Georgian Bay in Lake Huron.

### Crown Lake

Crown Lake is a headwater lake with only two small beaver ponds in its watershed. The lake has 6 permanent inflowing streams and 4 ephemeral inflows. The streams follow glacial-scoured bedrock valleys and therefore exhibit a strong angular drainage pattern. The Crown Lake watershed drainage area is small (3.63 $km^2$). The major inflow stream flows parallel to the lake shoreline for ~1 km before flowing to the lake.

Crown Lake empties to the north into Ragged Lake, which flows north into Smoke Lake. The Smoke Lake outflow joins the Oxtongue River which eventually reaches Lake Huron to the southwest.

## Nunikani Lake

The Nunikani watershed includes the watersheds of Havelock, Kennisis and Red Pine Lakes. All of these lakes enter Nunikani Lake at the north-eastern extreme through the Kennisis River. The Nunikani outflow enters Big Hawk Lake then flows through Halls, Boshkung and Mountain Lakes and into the Gull River. The Gull River empties into Lake Simcoe which ultimately reaches Georgian Bay in Lake Huron.

There are 11 streams flowing into Nunikani Lake, excluding the Kennisis River. The main stream channels generally flow north-east/south-west or east-west along the fault or gneissosity strikes.

Nine major waterbodies exist within the Nunikani watershed excluding the Kennisis River chain. Four of these waterbodies are in the Nunikani #4 subwatershed, the largest of the subwatersheds.

There are ponds in subwatersheds #7, #8, and #11. The three waterbodies of subwatershed #8 are a series of large beaver ponds. The flow rate of the Kennisis River is a primary influence on the flushing rate and chemistry of Nunikani Lake.

## Sherborne Lake

Sherborne Lake naturally flows west to St. Nora Lake; however, water management control during the high-flow spring season, results in discharge from the most southerly tip of the lake into Big Hawk Lake. The natural outflow entering St. Nora reaches Boshkung Lake via Kushog Lake. The water managed outflow, entering Big Hawk Lake, reaches Boshkung Lake via Hall's Lake to the south. Boshkung Lake reaches the Gull River by a series of lakes and rivers and eventually flow into Lake Simcoe and ultimately Georgian Bay on Lake Huron.

The major inflow streams of Sherborne Lake are all on the north of the lake. The southern watershed boundary is only a few hundred meters from the shoreline. The two major inflow streams flow several kilometers southward before entering the lake. Many small lakes and ponds are found in this northern section of the watershed.

## 4. WATERSHED DESCRIPTION

### Big Porcupine Lake

Big Procupine Lake is a large, complex shaped lake with several small lakes within its watershed (Figure 8, App. 2). The largest of the six subwatersheds is south and west of the lake. The south and east watershed boundary is near the lake shoreline. The central body of the lake connects to a north and a south bay by a series of narrow channels.

Biotite gneiss is the main bedrock although two eliptical felsic intrusive plugs dominate the southern highland areas of the watershed. The biotite gneiss strikes north-east/south-west and dips at approximately 30 degrees to the south.

Thin till and rock ridges dominate the surficial geology. Large minor till plains exist to the east, west and south of the main lake body. Large, permanently flooded, peat bogs are to the south-east of the main body of the lake. The bogs extend inland several kilometers linking the main lake body to the two large ponds in subwatershed #5. The expansive bog complex is associated with sinuous sand beds which, combined with the bogs, link the main lake body to the south-west corner of the watershed.

Subwatershed #5 is the largest subwatershed and contains a small river which meanders through a peat bog before entering the main lake body. The exposed bedrock areas strike in a north-east/ south-west direction and represent steep cliff faces or ridges.

A coniferous forest dominates the peat and sand area, and a mixed forest occurs on the thin till and rock ridge areas. The deeper till of the minor till plain has a hardwood forest.

### Clear Lake

Clear Lake is a small Precambrian Shield lake with no continuously flowing inflows (Figure 11, App. 2). The six ephemeral streams flow only during the early spring and immediately after major precipitation events. The bedrock type is biotite gneiss, with traces of small marble interbeds. The bedrock is cut by numerous fault lineaments which strike north-east/south-west

parallel to the gneissosity strike. The dip of the bedrock slopes to the south-east at an angle of approximately 25°.

The Clear Lake watershed is extremely small and at no point does it extend greater than 400 meters from the lake.

Thin till and rock ridges dominate the watershed. Five tiny lobes of moderately thin till are present but of minor significance. Four small pockets of peat are also present with the largest adjacent to Clear Lake's west bog. Many rock ridges, striking north-east/south-west are in the watershed area.

The catchment is almost entirely covered with a conifer forest (mainly hemlock).

## Crown Lake

Crown Lake is an oligotrophic headwater lake (Figure 14, App. 2) with a rectangular island in the main basin. A narrow north-eastern arm and narrow channel leads to a southern bay. The small rugged watershed has north-east/south-west striking granitized gneiss bedrock which dips to the south-east at approximately 30 degrees. The six subwatersheds have streams that are small and less than one kilometer in length. The dominant surficial cover is thin till and rock ridges in the elevated areas of the watershed. There are several minor till plains in the watershed and a deep level kame deposit is present south of Crown Lake's south bay. Sand deposits occur between the south bay and the main lake body and extend north from the north-east bay. Peat deposits occur in the numerous small bedrock pockets and one elongated valley in the north-east section of the watershed. Exposed bedrock is found in a north-east and south-west trending ribbon representing either ridges or cliffs. The vegetation is mixed forest, with coniferous species dominating the steep, rugged thin till and rock ridges and bog areas. The sand deposits have a mixed forest cover. The deeper till and kame deposits have a hardwood forest, mainly maple. The streamwaters are dilute and of low alkalinity due to the relative insolubility of both the bedrock and surficial material present in the watershed.

Nunikani Lake

Nunikani Lake is an oligotrophic non-headwater lake (Figure 17, App. 2). The main influx of water into the lake comes from the Kennisis River. The river drains the large watersheds of Redstone and Kennisis Lake among others. The immediate watershed has a north-east/south striking biotite gneiss, dipping approximately 30° to the south-east and a centrally located quartz monzonite zone. A marble bed several meters wide, with numerous small marble inter-beds on both sides of the main bed, parallels the eastern shore of the lake.

The ten streams which drain directly into Nunikani Lake are first and second order streams. The largest stream is in the western part of the watershed and contains many large ponds. It flows into the tip of the north-eastern arm of Nunikani lake.

The surficial cover of Nunikani Lake is primarily thin till and rock ridges. The presence of disseminated marble in the thin till in the south-eastern portion of the watershed is quite unique in the Algonquin-Haliburton region. This results in higher pH and alkalinity in the streams draining from this area. Zones of more continuous thin till appear throughout the watershed although none is of sufficient depth to qualify as a minor till plain.

An outwash deposit is found in the north-eastern corner of the watershed where the Kennisis River enters the lake. Peat deposition occurs in the numerous bedrock pockets and the larger wetland area adjacent to subwatershed ponds. Exposed bedrock occurs in small ribbons parallel to the bedrock strike of the major faults. Several larger bedrock expanses are north-east of the large pond in the north-eastern portion of the watershed.

Conifers dominate the vegetation in the thin till, rock ridges and bog areas. Hardwoods (mostly hard maple) dominate in the deeper till areas.

The streamwaters of the west and north side of Nunikani have low pH, alkalinity and dilute chemistry typical of non-carbonate watersheds. The streams along the eastern shore of Nunakani have higher pH and alkalinities as a result of the marble bed and the disseminated carbonate material in the till. Calcium is also higher in concentration in these subwatersheds because of the influence of the carbonate material.

## Sherborne Lake

Sherborne Lake is an oligotrophic lake with four arms diverging from the main body, which contains several large islands (Figure 20, App. 2). Each arm of this complex lake has numerous bays and each arm receives drainage from at least two streams. Most of the watershed lies north of the lake, the southern watershed line parallels the southern shoreline only 300 meters inland.

The lake has fourteen subwatersheds, with some of the north watersheds containing lakes.

The bedrock consists of a centrally located north-east/-south-west striking biotite gneiss, a south-east dipping complex with ortho-gneiss beds to the west and a section of quartz monzonite to the east.

The dominant surficial cover in all watersheds is thin till and rock ridges. Generally, the larger bedrock outcrops are in the north and western sections of the watershed. Areas of deeper till are in the southeast portion of the watershed. A large minor till plain is between the north and eastern arms of Sherborne Lake. Two small pockets of outwash sand and gravel deposits are along the north and south arm of Sherborne Lake.

The larger peat bogs are in the low valley zones in association with the ponds of this area. The vegetation is a coniferous forest, but hardwoods (mainly maple) dominate in the deeper and more continuous till areas. The peat areas contain either rushes and reeds or spruce and Sphagnum, depending on the drainage.

The stream waters of Sherborne Lake are very dilute and have low pH and alkalinity. The stream draining the largest and deepest till deposit has the highest pH and alkalinity of the fourteen streams.

## 5. GEOLOGIC HISTORY

The five watersheds lie in the Grenville Province of the Canadian Shield. The geology of the watersheds reflect the two distinct formational processes.

The Grenville orogeny is predominately responsible for rock formation and mountain building, followed by subareal erosion which characterizes the bedrock geology. The second formational process was the Wisconsin glaciation which directly or indirectly resulted in the glacial deposits that overlay the Grenville bedrock. The geologic time scale is in Table 2. The geologic history of the Algonquin-Haliburton is shown in Table 3.

The Grenville orogeny produced a rectangular land mass, known as the Grenville Province, which stretches from Georgian Bay on Lake Huron to Labrador. The extensive folding during the Grenville Orogeny produced north-east to south-west trending beds in the study area.

In addition to folding the metamorphism, the Grenville rock has also undergone extensive faulting and infrequent intrusition of more basic igneous material. The bedrock folding affects local watershed topography with more resistant beds tending to form ridge areas. The major fault set affected lake basin shapes and stream channels, which follow the fault lines. Since the end of Grenville orogeny, this seismically inactive area has intense subareal and glacial erosion.

The watersheds are part of a large regional dome resulting from two anticlinal forms with axis north-west/south-east and south-west/north-east. Outlines of paleozoic rock occur in the region, however none are found within the watersheds. The extended period of subareal erosion, since the Grenville orogeny, creates a peneplain on the regional scale and a local relief of alternating lake and swamp filled valleys, separated by cliffs and ridges. Although subareal erosion is a major factor in determining the topographical characteristics of the region, the Pleistocene glacial period significantly modified the bedrock and is responsible for the deposition of the unconsolidated material present.

Table 2: The geologic time scale (from Krauskopf 1976)

| Era | Period | Epoch | Time Before Present ($10^6$yr) |
| --- | --- | --- | --- |
| PHANEROZOIC | | | |
| Cenozoic | Quaternary | Recent | 0.01 |
| | | Pleistocene | 2 |
| | Tertiary | Pliocene | 10 |
| | | Miocene | 27 |
| | | Oligocene | 38 |
| | | Eocene | 55 |
| | | Paleocene | 65-70 |
| Mesozoic | Cretaceous | | 130 |
| | Jurassic | | 180 |
| | Triassic | | 225 |
| Paleozoic | Permian | | 260 |
| | Pennsylvanian | | 310 |
| | Mississippian | | 340 |
| | Devonian | | 405 |
| | Silurian | | 435 |
| | Ordovician | | 480 |
| | Cambrian | | 550-570 |
| PRECAMBRIAN | | | |
| Proterozoic | | | 2,500 |
| Archean | | | 3,500 |

Table 3: Geologic history of the Algonquin-Haliburton area

| Geologic Time* (millions of years before the present) | Geologic Event | Processes |
|---|---|---|
| 3,500 | | - Deposition of volcanics and clastic sediments |
| Arkean Era 2,480 | Kenoran Orogeny | - Rock metamorphism, folding and intrusion by granite rocks followed by long erosional period |
| 1,735 | Hudsonian Orogeny | - Orogenic episodes separated by substantial erosional intervals |
| 1,370 | Elsonian Orogeny | - Sediments deposited at this time are better sorted than Archean sediments and have significant occurrence of limestone |
| Proterozoic Era 955 | Grenville Orogeny | - Major deformational events in the study area (folding, faulting, metamorphism, intrusion by granitic and diabasic rods)<br>- Most evidence of previous events was obliterated by Grenville deformation<br>- Crystal stabilization |
| Paleozoic Era 550-260 | | - Sediment deposition during the Paleozoic |
| 0.1 | Glaciation | - Subareal erosion |
| Mesozoic Era | Wisconsin | - Glacial removal of Paleozoic sediments<br>- Glacial grinding and removal of less resistant Precambrian Shield rock<br>- Deposition of ground moraine, drumlins, etc.<br>- Deposition of glacial proximal deposits, kame<br>- Deposition of Glacio-lacustrine deposits<br>- Isostatic rebound and corresponding drainage<br>- Subareal erosion and lake sedimentation readjustment<br>- Peat deposit and alluvial disposition |

## 6. BEDROCK GEOLOGY (REGIONAL)

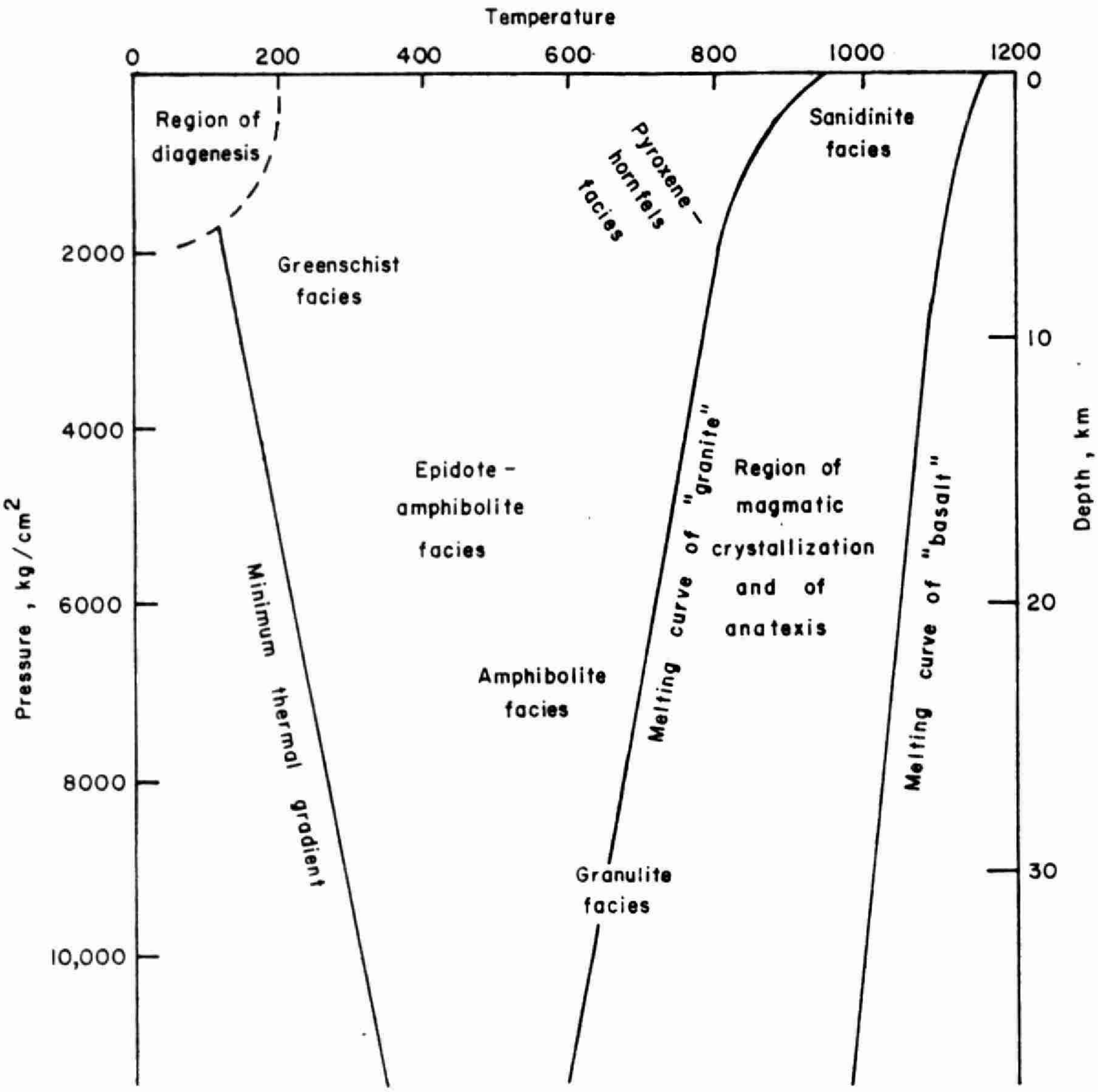
The three major rock classifications are sedimentary, metamorphic, and igneous. Sedimentary rocks are typically formed in low temperature and pressure regimes as a result of the weathering of previously-deposited material or precipitation from aqueous solutions. Sedimentary rocks are at equilibrium near surface and become less stable as they are buried under more recent deposits. Igneous rocks which result from the cooling of silicate melt are unstable at temperatures less than 700 degrees centigrade. Volcanic igneous rock which form at the earth's surface will be in chemical equilibrium at similar pressures to sedimentary rocks and at depth will be unstable at high temperature. The conditions leading to the metamorphism of sedimentary and igneous rock types are found at depths of 3 to 20 kilometers under the earth's surface. Metamorphic rocks, developed at temperatures ranging from 300 to 1100 degrees centigrade, may be both structurally and mineralogically different from the parent rock type. Classically the formation of metamorphic rocks proceeds as solid phase transition.

The characteristics of a metamorphic rock are largely dependent on three factors:

a) composition of the parent sedimentary or igneous rock,
b) prevailing temperature, and
c) prevailing pressure

Compositional constraints of the parent material results in metamorphism of carbonate-rich limestones to carbonate-rich marbles, and silicate-rich shales to silicate-rich slates. The temperature and pressure experienced during metamorphism determines the grade of metamorphism as illustrated in Figure 2. The grade of metamorphism common to the Algonquin-Haliburton region is Amphibolite facies and in some instances the Granulite facies. The bedrock of the Algonquin-Haliburton region while undergoing high-grade metamorphism has attained temperatures and pressures approaching the melting point of granite.

FIG. 2: Metamorphic facies in relation to temperature and pressure (from Mason 1966)



The two types of metamorphism are contact and regional. Contact metamorphism occurs adjacent to magmatic intrusions. The metamorphozed zone between the magmatic intrusion and the unaltered host rocks is often only a few kilometers in width and represents a steep geothermal gradient. Generally contact metamorphism is restricted to within a few kilometers of the earth's surface and thus is of minor significance in the Algonquin-Haliburton area. Regional metamorphism is associated with the large-scale folding of thick rock sequences and the subsequent formation of mountains. The compression of the Grenville Province against the older shield rocks during continental collision resulted in the Algonquin-Haliburton rocks being subjected to extreme pressure and high temperatures as they became the roots of large fold mountains. The Algonquin-Haliburton metamorphozed bedrock originated as the mountain roots which were exposed by continuous subareal erosion. The regionally metamorphozed rocks of the study area often exhibit characteristics of both metamorphic and igneous rocks since their formation occurred at temperatures and pressures near the melting point of the rock mass. The possible simultaneous metamorphism and injection of igneous material further complicates the geology of the region. The injection of sufficient quantities of igneous material into the host rock results in a contorted migmatic rock mass having zones of granitic material swirled in more typically metamorphic rock. The presence of a liquid phase under pressure may cause the liquid to intrude surrounding rock types resulting in dykes or pegmatite inclusions. Small pegmatite veins are common in the study area attesting to the high temperatures and pressures imposed on the region. The distinctive fabric of metamorphic rocks evolved as a result of the growth of crystals in a more or less solid phase. Metamorphic rocks are composed mineralogically of mica, amphibole, feldspar and have a different crystal orientation than the igneous rocks. Auxillary minerals typical of metamorphic rocks include rutile, talc, garnet, chlorite, and tourmaline. The most distinctive feature of regionally metamorphozed rocks is the presence of shear stress induced "foliation gneissosity". The tendency of tabular micaceous and prismatic amphibole minerals to orient themselves parallel to the plane of foliation is unique to regionally metamorphozed rocks. Mineralogic segregation is common

FIG. 3: Bowen's Reaction Series for Mineral Crystallization from a Cooling Magma

<u>Discontinuous Series</u>

Olivene

Pyroxene

(Fe/Mg increasing)

Pyroxene

Hornblende

Biotite

<u>Continuous Series</u>

Anorthite

Bytownite

Labradorite

Andesine

Oligoclase

Albite

Potash Feldspar

Quartz

Zeolite

Water-rich solutions

in virtually all metamorphic rocks and is responsible for the banded appearance of the rocks. Previous studies have generally concluded that fine scale banding in the order of a few centimeters is indicative of the sedimentary origin of the rock. Bowen's reaction series for the crystallization of minerals from a cooling magma is given in Figure 3. Bowen's reaction series also indicates the instability or weathering rate since minerals crystallizing at high temperature will be less stable at the earth's surface.

## 7. ROCK TYPES OF THE ALGONQUIN-HALIBURTON REGION

The following bedrock types are present in the Algonquin-Haliburton region:

1. Biotite-Gneiss (granite) - possibly the most common of bedrock types in the region and is composed of biotite, potassium depleted feldspar and quartz. Minor components include horneblende or garnet. They originate from the metamorphism of clays, shales and mudstones, and exhibit fine-scaled banding often attributed to their sedimentary origin. Equigranular and of moderate mineral grain size, the bands of light-coloured feldspar and quartz are separated by aligned micaceous minerals. Weathered outcrops are grey to brown in colour and banding is emphasized by the weathering grooves along the mica enriched bands.
2. Ortho-Gneiss - a relatively homogeneous rock of igneous origin generally void of metasedimentary characteristics. The ortho-gneiss is an equigranular feldspar and quartz rock, showing weak banding and slight foliation. Biotite content of the rock seldom exceeds ten percent. Zenoliths of metasedimentary biotite are probable evidence of relatively complete replacement of original bedrock by the granitic mass.
3. Monzonite - is an igneous intrusive rock, intermediate in composition between syenites and diorites. The relatively coarse-grained equigranular rock contains approximately equal quantities of potash, feldspar and plagioclase. The Algonquin-Haliburton monzonite may approach ten percent quartz content and is referred to as quartz monzonite. The dominant mafic components are biotite and horneblende in quartz rich monzonites and augite, hypersthene and olivine in the more basic monzonites. Increase in quartz grades monzonites into adamellites and increases in mafic contents result in kentallenites. The quartz monzonite of the study area is generally pink in colour with faint foliation and some banding.
4. Diorite - is an intermediate igneous plutonic rock with its primary mineral constituents being plagioclase, amphiboles and pyroxene. Diorite is equigranular and has a medium grain size and foliation is limited or absent. The quartz diorites common in the Algonquin-Haliburton region are more acidic in nature and are near

granodiorite in composition. The relative quartz rich diorites of the study area have a light and dark speckled appearance and are often referred to as tonalites.

5. Ultramafic - dark coloured rocks containing less than 45 percent silica. The ultramafic rocks are mineralogically composed of pyroxene, olivine and minor amounts of plagioclase. They are very rare in occurrence in the study area. The iron and magnesium-rich rock weather very quickly.

6. Pegmatites - form when residual fluids, during rock solidification, develop under pressure and cut the existing rock in veins. Pegmatites in the study area, range from several centimeters in width in biotite-gneiss rock, to several metres in width in igneous diorites. The extreme high grade metamorphism, experienced by the Algonquin-Haliburton region, would make the rocks extremely susceptible to the intrusion of pegmatites and the possibility of partial melting of the host rock could produce pegmatites locally. Generally the pegmatites of the study are composed of quartz and alkali feldspar and exclude the vast list of accessory minerals found in pegmatites in other parts of the world. Pegmatite veins, due to extremely slow cooling, may exhibit mineral zoning from the wall rock to the center.

7. Schist - may be distinguished from gneiss by its lack of mineralogical banding although it still pssesses a marked textural foliation. Relative to the genesis of gneiss, schist may form in response to regional metamorphism of lower grade, or due to compositional constraints. This second reason is probably most important in Muskoka-Haliburton since inter-layered gneiss and schist have been found. Biotite, quartz and feldspar are the dominating minerals.

8. Quartzite - when an extremely quartz-rich rock such as a pure sandstone is metamorphozed, a quartzite results. Quartzite is composed of irregular quartz grains (0.1-0.5 mm) fused together along with minor biotite, horneblende, and feldspar. Due to the crystallographic characteristics of quartz, the obvious foliation observed in many metamorphic rocks is not present in quartzite. Colour may be variable and is usually dependent on the type and quantity of chemical impurities present in the rock.

9. Meta-Arkose - results from the metamorphism of an impure sandstone or other quartz-rich rock. Hence, it is similar in appearance to quartzite (i.e., being principally quartz) but contains a small but significant amount of alumino-silicate minerals, notably feldspar and biotite.

10. Marble - is a product of the metamorphism of limestone and dolomite. Marble is composed of large calcite or dolomite crystals and foliation is generally weak unless biotite or tremolite minerals are present. The marble is generally light in colour and foliation is a result of sub-parallel alignment of lensoid grains. Marble occurs in rare thin beds in the study area in the midst of relatively continuous silicate beds. Metamorphism of the marble has resulted in the formation of Ca and Mg rich minerals in the contact zones with the silicate bedrock.

11. Migmatite - are a result of coincidental igneous and metamorphic rock formation. Migmatites are composed mainly of quartz and feldspar minerals although certain bands in a migmatite may have a high mafic content. The banded and swirled nature of migmatites make representative sampling extremely difficult.

12. Gabbro - appears as intruded basic igneous "plugs" throughout the Algonquin-Haliburton region. The medium- to coarse-grained black coloured rock, whose mineral components are plagioclase, augite, hypersthene, horneblende and olivene. The gabbro intrusions cut host rock boundaries due to the implanted nature of the intrusion. Increase in mafic content results in grading into the ultra-mafic rock types which are called metagabbros.

13. Amphibolite - form by metamorphism of calcium, iron and magnesium-rich basic rock of either igneous or sedimentary origin. Generally amphibolite derived from basic igneous rocks tend to be equally abundant in horneblende and plagioclase while quartz and biotite are minor constituents. Amphibolite derived from calcareous sediments contains horneblende as its primary mineral with an increase in quartz and biotite and a decrease in plagioclase relative to those of igneous origin. The foliation in amphibolites is generally due to the orientation of the horneblende mineral grains.

## 8. BEDROCK GEOLOGY (WATERSHED)

### Big Porcupine Lake

The bedrock composition of Big Porcupine Lake is north-east/-south-west striking biotite gneiss and felsic instrusive rock (Figure 9, App. 2). A typical sample of the biotite gneiss shows light and dark banding on a 1 to 5 centimeter scale. The darker banding is rich in mica and the lighter bands are rich in feldspar, and, in a few cases, quartz. The gneissosity of the biotite is dependent on the concentration and alignment of the plate-like minerals in narrow beds, several millimeters apart, which parallel the large scale banding. The biotite gneiss, which includes metamorphized beds of greywacke, arkose and sandstones, shows considerable variation in any one outcrop.

The gneissosity of the felsic intrusive shows a 20° dip to the south-east with slightly gentler dipping than the biotite gneiss gneissosity. The intrusive is mostly equigranular feldspar with minor mafic and quartz. The biotite gneiss is ortho-gneiss near the intrusive. The core of the intrusive forms large, resistant, dome-shaped hills in the south-central and south-east portions of the watershed. The glacial abrasion of the intrusives produced scoured and subrounded bedrock outcrops unlike the steplike cliff faces associated with biotite gneiss bedrock.

### Clear Lake

The bedrock of Clear Lake (Figure 12, App. 2) is biotite gneiss striking north-east/south-west and dipping gently to the south-east. Small feldspathic dykes within the watershed are part of the larger faults. Small quartz strings are also common throughout the watershed. A typical sample of the biotite gneiss shows light and dark banding on a 1 to 5 centimeter scale. The darker banding is enriched in mica and the lighter bands are enriched in feldspar and in some cases quartz. The gneissosity of the biotite is dependent on the concentration and alignment of the plate-like minerals in narrow beds, several millimeters apart, which parallel the larger scale banding. The biotite gneiss, whose composition is of

metamorphized beds of greywacke, arkose and sandstones, shows considerable variation in any one outcrop. Small marble interbeds are in the south-east corner of the Clear Lake watershed.

### Crown Lake

The bedrock of Crown Lake (Figure 15, App. 2) is biotite gneiss striking north-east/south-west and dipping gently to the south-east. A typical sample of the biotite gneiss shows light and dark banding on a 1 to 5 centimeter scale. The darker banding is enriched in mica and the lighter bands are enriched in feldspar, and in some cases quartz. The gneissosity of the biotite is dependent on the concentration and alignment of the plate-like minerals in narrow beds, several millimeters apart, which parallel the larger scale banding. The biotite gneiss, which includes metamorphized beds of greywacke, arkose and sandstones, shows considerable variation in any one outcrop, however, no marble interbeds are present in the watershed. Although biotite gneiss is the predominant bedrock type, beds of horneblende gneiss, impure quartzite and ortho-gneiss are a part of the biotite gneiss. Small feldspathic dykes are within the watershed and are a part of the larger faults. Small quartz strings are also common throughout the watershed.

### Nunikani Lake

The dominant type of bedrock is north/south to north-east/south-west striking biotite gneiss with a south to east dip of 25° (Figure 18, App. 2). A typical sample of the biotite gneiss shows light and dark banding on a 1 to 5 centimeter scale. The darker banding is enriched in mica and the lighter bands are enriched in felspar, and in some cases quartz. The gneissosity of the biotite is dependent on the concentration and alignment of the plate-like minerals in narrow beds, several millimeters apart, which parallel the larger scale banding. The biotite gneiss, which includes metamorphized beds of greywacke, arkose and sandstones, shows considerable variation in any one outcrop.

Small feldspathic dykes are in the watershed and are a part of the larger faults. Small quartz strings are also common throughout the watershed.

The biotite gneiss contains a 3- to 5-meter wide marble bed which strikes north-east/south-west parallel to the eastern shore of Nunikani Lake. The main marble bed is offset about 100 meters by an east/west striking fault in the south-east corner of Nunikani watershed. The main marble bed centers numerous thin beds of marble which are a part of the biotite gneiss. The marble bed pinches out at the west shore of subwatershed #7's most northerly pond. The biotite gneiss bed is cut by a several hundred meter wide quartz monzonite band. The quartz monzonite lacks the mica present in the biotite gneiss and quartz is more concentrated in this rock of igneous origin.

## Sherborne Lake

The Sherborne Lake watershed (Figure 21, App. 2) is underlain by biotite gneiss, intermediate ortho-gneiss, quartz monzonite and isolated gabbro plugs. The central and south-east portions of the watershed are a north-east/south-west striking biotite gneiss which dips to the south-east at approximately 30°. The western portion of the watershed is intermediate ortho-gneiss which also outcrops in a small oval section in the central biotite gneiss. The intermediate ortho-gneiss, being resistant to glacial erosion, produces a number of subrounded ridges of exposed bedrock. The biotite gneiss strikes north-east/south-west to north/south and dips gently south. A typical sample of the biotite gneiss shows light and dark banding on a 1 to 5 centimeter scale, with the darker banding being enriched in mica and the lighter bands enriched in feldspar and in some cases quartz. The gneissosity of the biotite is dependent on the concentration and alignment of the plate-like minerals in narrow beds, several millimeters apart, which parallel the larger scale banding. The biotite gneiss, which includes metamorphized beds of greywacke, arkose and sandstone, shows considerable variation in any one outcrop. Small feldspathic dykes occur within the watershed and are a part of the larger faults. Small quartz strings are also common throughout the watershed.

The quartz monzonite is a variable width band cutting the biotite gneiss in a north-east/south-west direction only. The monsonite is feldspar with some quartz.

Gabbro plugs are in the biotite gneiss and the intermediate ortho-gneiss. The plugs are less than 150 meters in diameter and represent the only felsic bedrock found in the watershed.

## 9. BEDROCK STRUCTURE AND IMPLICATIONS

### Big Porcupine Lake

Big Porcupine Lake centers around two major regional faults. The north-west/south-west striking fault cuts the outflow and the north bay in the north and is at the center of the elongated south bay and Tea Lake in the south. A second major fault strikes north-east/south- west through the north bay, and forms the north-west boundary of the main lake body and the major bog of subwatershed #5. Secondary faults form the south boundary of Big Porcupine's main lake body and the southern axis of the main bog of the watershed. The lineaments generally strike north-east/south-west with distortion occurring around the major felsic intrusions.

Generally, the stream channels are angular in nature, and tend to follow bedrock faults and lineaments. The smaller lakes and ponds of the watershed have both their location and shoreline determined by the faults and bedding associated lineaments of the watershed.

### Clear Lake

The major faults and lineaments of the Clear Lake watershed strike north-east/south parallel to the bedrock gneissosity. The major fault enters the lake in the north-east corner and exits the watershed at the southern extremity forming the lake outflow. A parallel fault forms the western boundary of the lake.

The lake is the result of glacial scouring between the two major north-east/south trending larger faults at the point of intersection with a poorly defined, north-west/south-east fault set.

### Crown Lake

The main physical features of the Crown Lake watershed include gneissic bedrock striking south-west/North-east and dipping 30° to the south-east, a primary fault, which runs from the outflow in the north and forms the channel connecting the south bay to the main body of the lake, and a north-west/south-east trending fault set.

Glacial scouring of the structurally weakened bedrock occurs at the intersection of the primary fault with the north-west/ south-east fault set. Southward glacial movement created the main basin by removing large quantities of bedrock between the two main north-west trending faults along the main fault axis. The actual long shorelines of the main lake tend to parallel the bedding strike, rather than closely following the primary fault. This seems to indicate that major faults determined the lake location, but more massive resistant beds, or parallel faults, determined the shoreline of the lake. The outflow neck to the north, and the steep-walled channel connecting the south bay to the main lake body, are apparently a result of glacial gouging of the weakened bedrock proximal to the primary fault. The influence of bedrock resistance on lake shape exemplified by the south-west/north-east elongation of the south bay is on strike with the south-west and north-east bay of the main lake body. The more resistance ridge, which terminate the east extent of the south bay, also extends over one hundred meters into the south part of the main lake body and is on line with the islands in the lake. This ridge forms the western boundary of the north-west bog. This same valley-ridge complex, which results in the elongation of the bogs, also contains the fluvial deposits of sand, where the strong south-west/north-east trend of the glacial-resistant ridges control the lateral boundaries. This same trend also influences the deep glacial deposits of the south-east which also extend up the valleys creating a strong south-west/north-east trend. The main stream channels tend to follow the south-west/north-east trend, with the north-east/ south-east fault set influencing the secondary drainage pattern.

The major cliffs, as well as the bedrock ridges in the thin till, also follow the major south-west/north-east lineation direction.

## Nunikani Lake

The main physical features of the Nunikani Lake watershed are a north-east/south-west fault pattern which coincides with the strike of the gneissosity. A smaller set of north-south trending faults influences the eastern section of the watershed. Several east-west

trending faults are also present, the largest of which forms the central axis of the watershed. Like many lakes in the region, Nunikani Lake exists at the intersection of two large faults. The north-east to south-west trending fault enters the watershed along the Kennisis River in the north and exits at the outflow at the south end of the lake. The east-west trending fault is responsible for the valley containing Nunikani's largest stream and the east arm of Nunikani Lake, which terminates at the regional north-east/ south-west fault.

Glacial scouring of debris along the two fault axis results in a Y-shaped lake with major influx of water to each of the northern arms and outflow from the southern arm. Nunikani's subwatersheds #1 and #2 drain simple V-shaped valleys into the south arm of Nunikani Lake. Nunikani subwatershed #4 has a first order stream flowing toward the main second order stream along the north-east/- south-west trending fault valley. The main second order stream flows along the same east-west trending fault which host the east arm of Nunikani Lake.

A large beaver pond dominates the central basin of subwatershed #6. The pond shoreline and the outflow result from the north-east/south-west fault patterns. The south-west/north-east elongate basin of subwatershed Nunikani #7 is a result of this same fault pattern. The appearance of Nunikani subwatershed #10 is almost identical to Nunikani #6 except the main pond and outflow and oriented along the east-west fault direction.

The numerous ponds and swamps reflect the two major lineament directions in both shape and location, similar to the stream patterns present.

The thin marble bed outlines the strike of bedrock (Figure 19, App. 2). The beds dip 25-30° to the south in most instances although, local folding or faulting causes local distortion of this regional trend. Since the bedrock gneissosity beds strike parallel to the main north-east/south-west fault set, the affect of each on the physical feature is difficult to separate. The major valleys follow the major faults, while differential weathering of variable resistant bedrock also affects the Nunikani watershed.

## Sherborne Lake

Factors affecting the character of Sherborne Lake include the resistant orth-gneiss bedrock in the north and west, a north/south to north-east/south-west striking south-east dipping biotite gneiss in the central and eastern section of the watershed, a major regional fault strikes north/south and exits through the south-east arm and has several parallel faults, a major north-east/south-west striking fault intersects the regional fault in the north bay and is parallel to the western shoreline of the main lake body, and an east/west striking fault contains the east and west arms of the lake.

Sherborne is a complex lake in shape because of glacial scouring of the intersecting point of three major faults and several smaller fault sets. The large north/south regional fault is structurally responsible for the large northern bog on the eastern shore of the main lake body and the long south-east arm of Sherborne Lake. This fault also forms the central valley, which contains Sherborne's largest stream. A parallel, but smaller, fault to the west contains the second largest stream. The major south-west/ north-east fault intersects the regional fault in the north bay and forms the western shore of the main lake body. The east-west fault is largely responsible for the east and west arms of Sherborne Lake. Other fault sets also play a significant role in the development of bays.

The ortho-gneiss bedrock relate directly to the large number and size of bedrock outcrops of the west and north portions of the watershed. The biotite gneiss, with a greater structural weakness along the plain of gneissosity, appear to have only ribbons of bedrock associated with it.

## 10. GLACIAL HISTORY

The Algonquin-Haliburton region experienced four major periods of glaciation during the Quaternary Period, namely the Nebraskan, Kansan, Illinoian and Wisconsin. Each glaciation lasted about 1,000,000 years, with interglacial intervals of warming climate and receding ice, known as the Aftinian, Yarmouth and Sangaman periods. The Wisconsin glaciation, being the most recent, obliterated almost completely any trace of the surficial depositions of the previous three glaciation periods in the study area. The south portion of the Algonquin region and all of Haliburton County are noted as regions of sparse, thin glacial deposits. The hard granitized bedrock has resisted glacial scouring and resulted in the development of an extremely thin basal till during glacial advance.

During retreat the glacial sediment load continued to move forward, delivering rocky debris to the glacier melt-zone. Thus, stabilization of the ice front developed deep end moraine and kame deposits. The absence of major ice contact surficial deposits in the south-western Algonquin region and Haliburton County indicates a steady ice retreat. The high elevation of much of the Algonquin-Haliburton region limited the effect of Lake Algonquin. The maximum level of the lake was 340 meters above sea level at Dorset. The steady glacial retreat experienced by the elevated Algonquin-Haliburton areas has been the major contributing factor in the deposition of surficial material.

Four stages in the Wisconsin glacial withdrawal (Fig. 4-7), influenced the critical changes in glacial lake outflow patterns and depositional influences on the Algonquin-Haliburton region. Figure 4 shows the ice glacier front along the Kirkfield, Fenelon Falls and Trent Valley system. Lake Algonquin encompasses both present day Lake Michigan and Lake Huron, and outflows southward into early Lake Erie and consequently into a large Post-Iroquois Lake.

The Algonquin-Haliburton region was under a thinning, forward-moving moving ice sheet, although the rate of melt did not exceed the southward horizontal movement for a short period of time and resulted in ice-front readvance.

FIGURE 4 - WISCONSIN ICE SHEET POSITION, 12,200 YEARS BEFORE PRESENT (FROM DOUGLAS 1976)

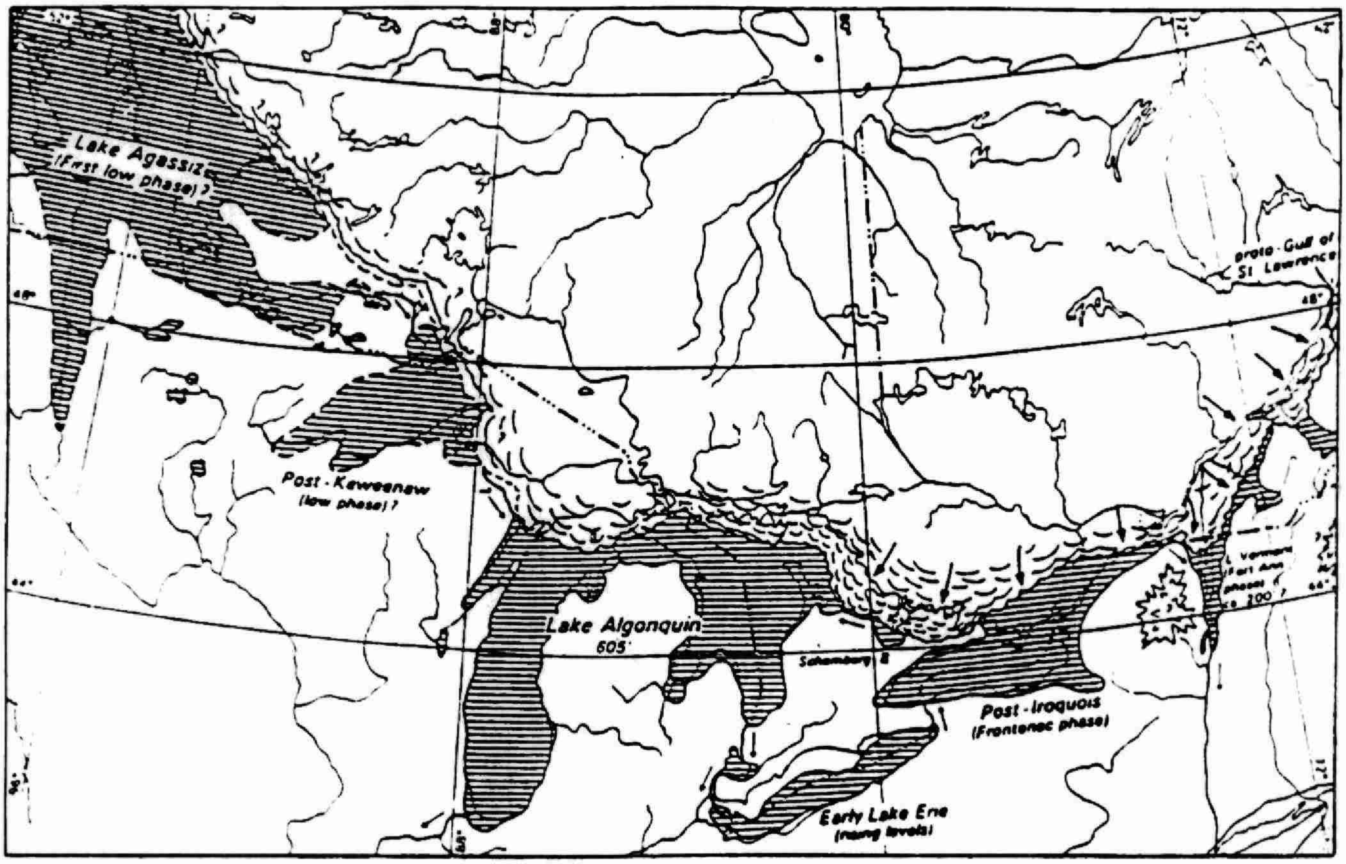
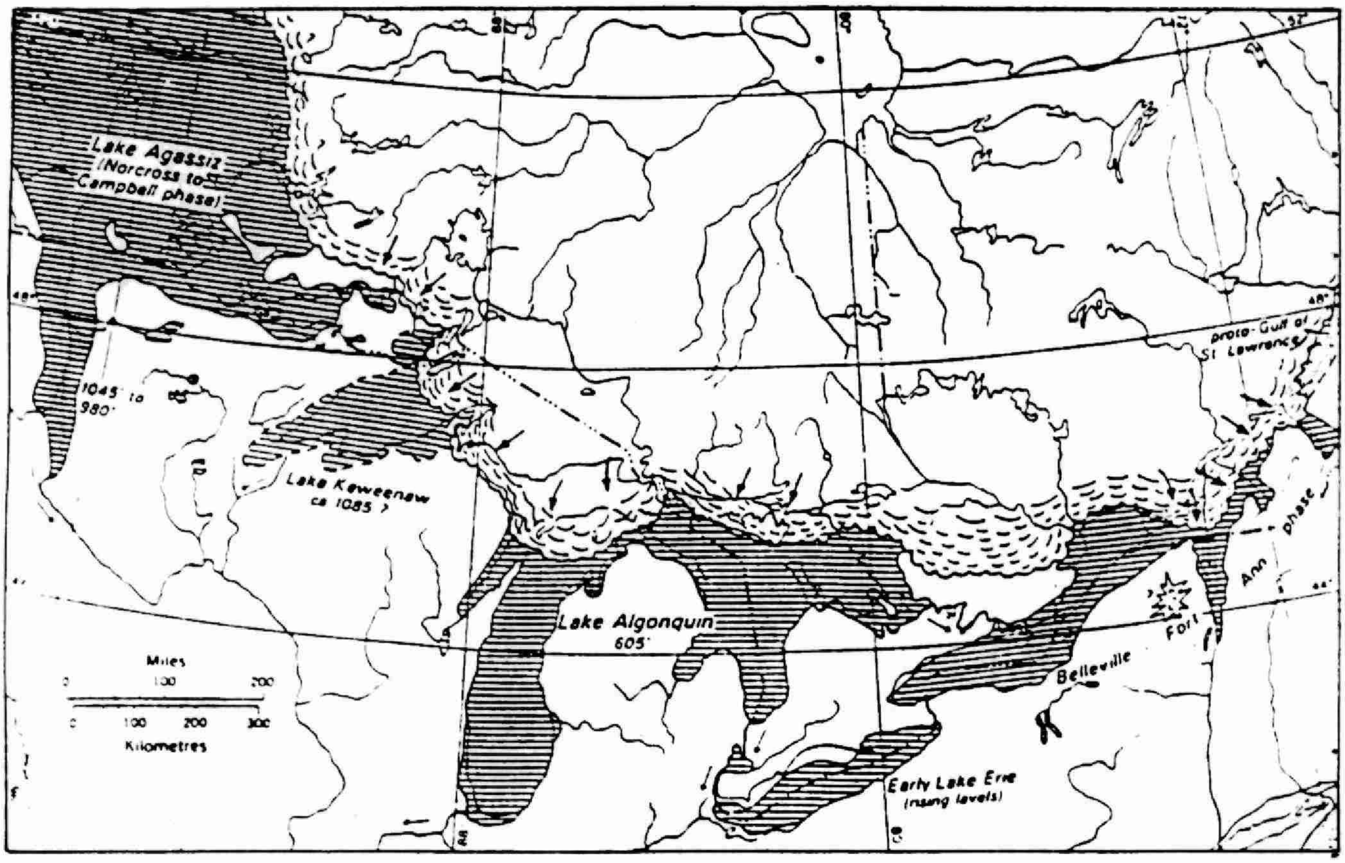



FIGURE 5- WISCONSIN ICE SHEET POSITION, 12,000 YEARS BEFORE PRESENT (FROM DOUGLAS 1976)



Georgian Bay was only partially revealed by the retreating ice and the Post-Iroquois Lake was much larger than present Lake Ontario. Also noteworthy is the mammoth Lake Agassiz in the present Lake Winnipeg basin. Following a minor ice advance the ice margin again retreated northward from the Kirkfield, Fenelon Falls and Trent Valley system to partially expose the study area (Figure 5). Lake Iroquois advanced at this point into the eastern Algonquin-Haliburton region and the low lying valleys of the western portion.

Lake Algonquin, at this time, had two outflows; a northerly outflow through the Lake Simcoe - Trent System directly into Post-Iroquois Lake and the original Port Huron outlet into Lake Erie. The "englacial" or melt out till and ice contact complex deposits occurred in the Algonquin-Haliburton region during this time. The deposition of outwashes also occurred during this period as the meltwater flowed southward and south-westward as the glacial sediment load swept off the glacier in large rivers and into the Precambrian valley.

The dome-shaped, complex valley/ridge nature of the study area resulted in continuously changing sediment transport routes as new valleys became free of ice and the drainage pattern readjusted. The deep lake basins of the Algonquin-Haliburton region remained ice-bound during this period of sediment mobility through the valley chains and thus prevented the filling of the deep lake troughs.

The third stage of ice retreat (Figure 6) shows the ice front along the northern boundary of the Algonquin region, Lake Algonquin expanding northward towards Lake Nipissing. This ice movement opened the Oxtongue spillway, allowing south-eastward sediment movement and eliminated major water movement through the present-day study lake area. Lake Algonquin returned to the solitary Port Huron outlet and local ice lobe expansion occurred in Superior and Michigan basin. Lake Erie expanded to its present size and Lake Ontario is at its lowest ebb.

The final stage of ice withdrawal (Figure 7) represents the end of glacial ice modification in the Algonquin-Haliburton area. The opening of the Fossmill outlet allowed discharge from Lake Algonquin, directly into the Champlain Sea in the St. Lawrence

FIGURE 6 - WISCONSIN ICE SHEET POSITION, 11,800 YEARS BEFORE PRESENT (FROM DOUGLAS 1976)

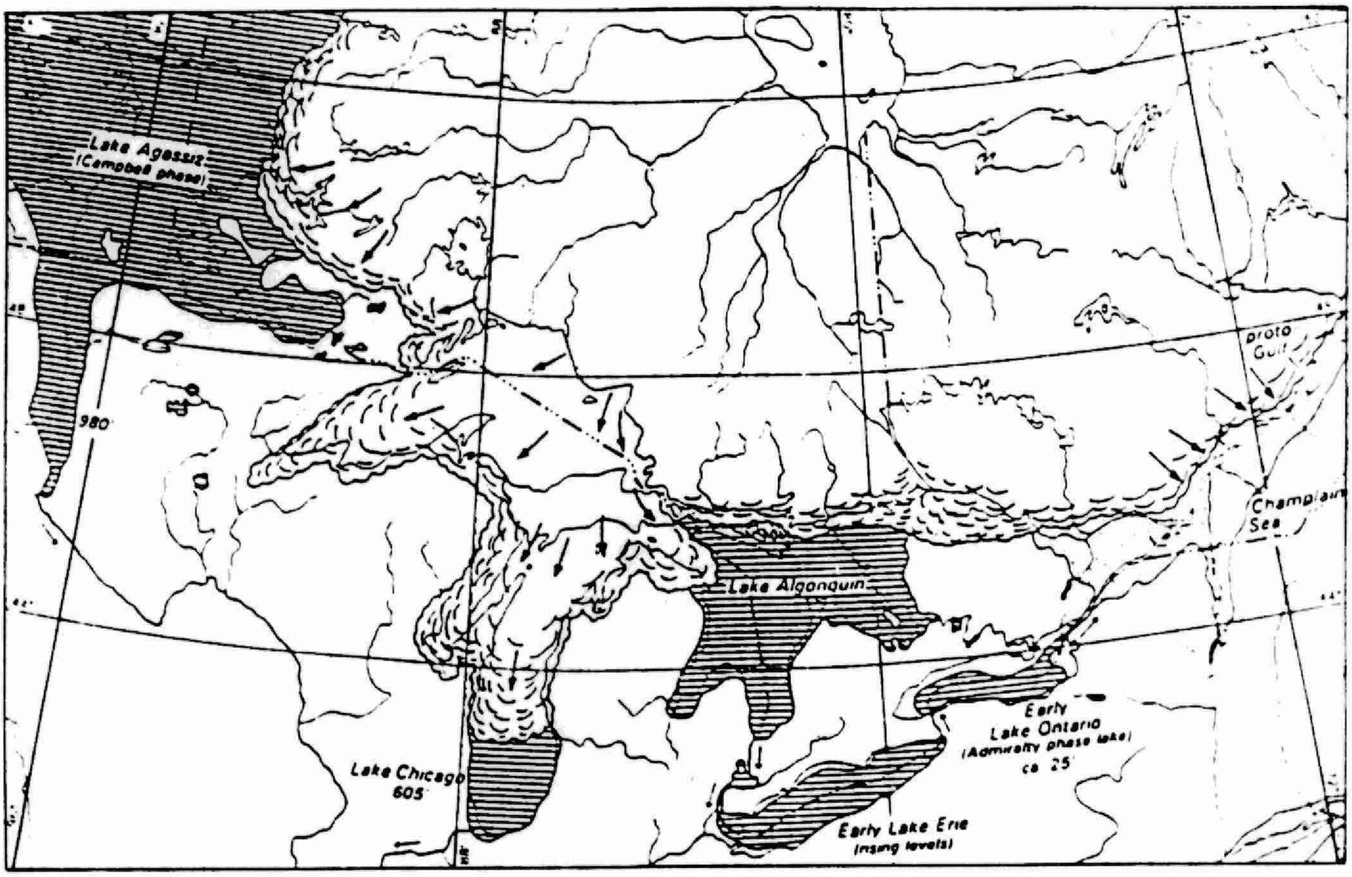
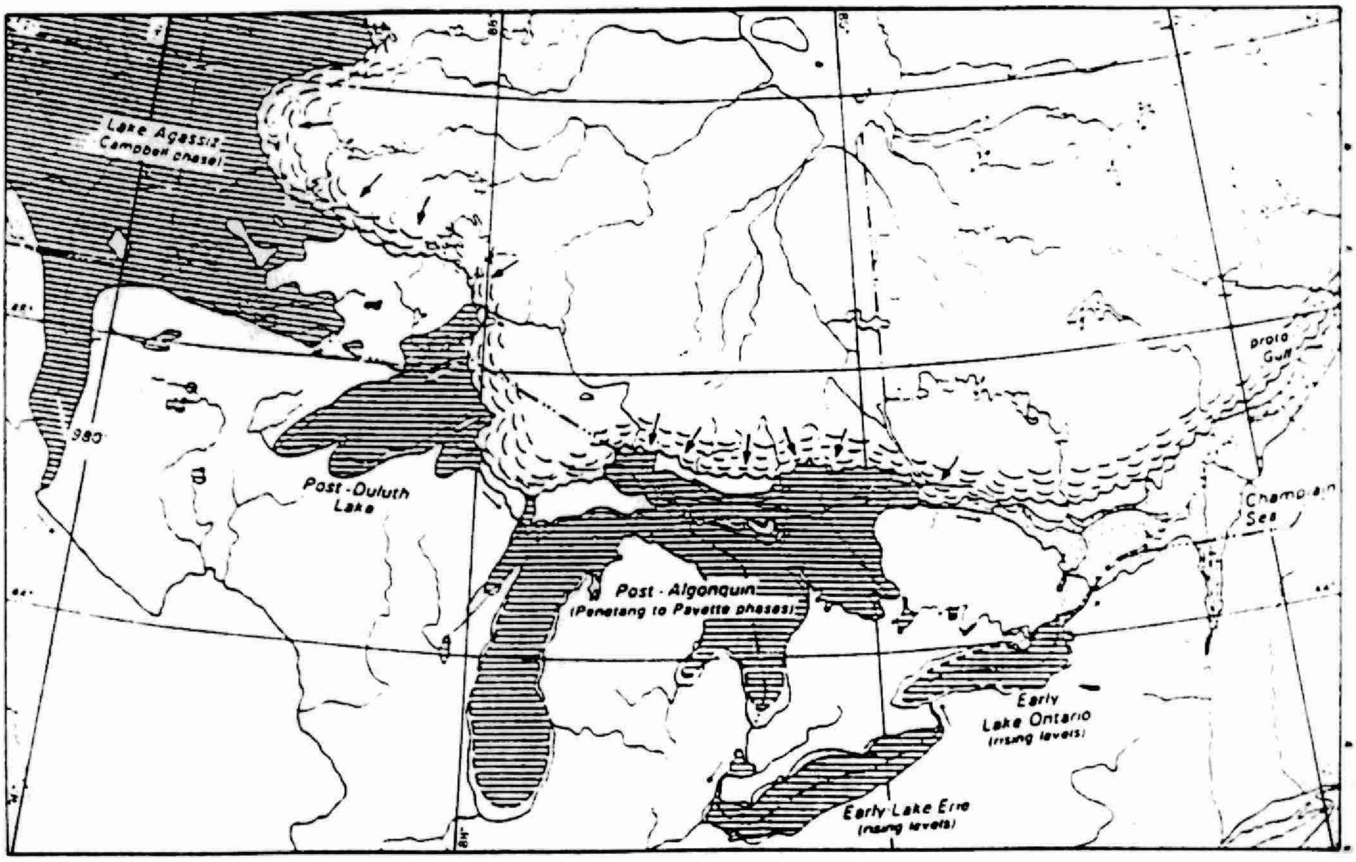



FIGURE 7 - WISCONSIN ICE SHEET POSITION 11,600 YEARS BEFORE PRESENT (FROM DOUGLAS 1976)



lowlands. The subsequent 67 m drop in the Lake Algonquin level effectively removed the glacial lake from the Algonquin-Haliburton region.

The unvegetated surficial deposit underwent considerable erosion while revegetation occurred. Peat accumulation in the zones of poor drainage began soon following the end of glacial influence.

## 11. GLACIAL DEPOSIT TYPES

The Algonquin-Haliburton region contains representatives of most known glacial deposit types within its boundaries. The following discussion includes the physical characteristics of all common deposits found in the area and the associated lake shoreline and stream drainage characteristics.

### 1. Till Plains

Till is the spatially dominate glacial deposit of the region and includes both subglacial "basal" till deposited by advancing ice and englacial "meltout" till deposited by the retreating ice sheet. Till, also known as "ground moraine", is a poorly sorted mix of sand, gravel and boulders. It generally exists as a discontinuous veneer over bedrock, with large floats or boulders melted out of the glacier lying on the surface. Large, dislocated boulders of upturned bedrock also commonly protrude from the till's surface. The thin till and rock ridges are divided on the basis of depth and prominence of exposed bedrock. Areas of continuous thin till (till plains) are shown for the study lake watersheds (Appendix 2). Lake shoreline in these areas generally consists of cobbles and boulders. Lake-till interfaces and streams flowing in thick till have a gravel boulder bed. In zones of thin till the stream channel generally flows on bedrock, littered with boulders.

### 2. Drumlins

Drumlins are asymmetrical, oval-shaped hills, generally of clay-enriched till material. The elongate axis of the drumlin is indicative of ice direction, with movement toward the narrow end of the deposits. The generally shallow amount of material and low clay content results in only a few drumlins in the lake watershed study area. However, drumlins are more common in the Minden area (to the south) and in the northern section of Algonquin Park.

3. Terminal Moraines

Terminal moraines resulting from the accumulation of debris at the edge of a stationary ice front are not found in the watershed of the study lakes. The consistent ice movement throughout the study area during both advance and retreat of the ice front is probably responsible for the absence of this deposit type.

4. Eskers

Eskers are formed by sinuous rivers flowing generally under, but possibly in or on the ice. These deposits form ribbon-like ridges easily identified on air photos and in the field. Eskers occur in the central region of Algonquin Park and are a part of the kame fields and drumlins. Lake shorelines, found by these eskers tend to be low-gradient littoral zones with broad, sandy beaches. Rivers or streams cutting across them exhibit heavy sand bed loads.

5. Kame

Kame deposits are often formed by rapid deposition in small temporary glacial lakes. Fluctuating lake levels result in many kame deposits being mixtures of fluvial and unsorted or partially sorted till material. Kame is more fluvial in nature and hence more sorted than till and much coarser and less sorted than eskers. Continuous opening of new outlets from these small glacial contact lakes created continuously changing conditions and an often complex deposition history. Kame deposits are found in abundance in Algonquin Park, in particular in the central and northern sections. Lake shorelines in these deposits are generally sandy. Stream channels tend to be cobble strewn with sand and gravel bedload. Large streams cut deep V-shaped valleys in the relatively deep kame deposits and also form small alluvium deltas at the stream mouth. Kames may also have small "kettle" or ice block, melt-out depressions on their surface, due to ice front proximity during formation.

6. Outwash Sand and Gravel

Sediment-laden glacial meltwater streams and rivers deposited sand and gravel in the broad valleys south of the ice front. Outwash deposits are mainly sand and silt, although gravels were often deposited during high flow periods. Abundant bedding, cross bedding and ripple marks attest to the fluvial origin of the deposit. Depressions in the outwash plains, caused by fragments of ice becoming lodged in the flood plains are now the sites of large bogs. Generally well-drained, the outwash or spillway deposits support many of the major highways in north-central Ontario.

Major spillways of the Algonquin-Haliburton region are along the Gull River in the south, Oxtongue River in the west, and the Lake of Two Rivers system to the north-east. Lake shorelines contacting outwash deposits form broad, sandy beaches and gently dipping, sandy littoral zones. Streams flowing in outwash deposits meander due to the low gradient, and have well sorted sand and gravel streambeds.

7. Lacustrine

Lake Algonquin received major fluxes of sediments during the melting of the Wisconsin ice sheet. Near-shore deposits of sand gave way to silt deposition at moderate depth and eventually to clays in deep-water. High-flow melt periods caused silt intrusion into the deeper portions of the ice contact lakes and resulted in thin, alternating beds of clay and silt or "varves". Deposits of this type occur along the Highway 11 corridor to the east, the Gull River System, and to the north-east of Algonquin Park. Shorelines in contact with lacustrine deposits tend to have clay bottoms. Streams typically cut down to the more resistant clay beds.

## 12. SOILS

The following very brief discussion of Algonquin-Haliburton soils is summarized from Jeffries and Snyder (1983). The soils of Algonquin-Haliburton region have developed during the past 12,000 years since the recession of the Wisconsin ice sheet. The coarse grain-size and the sparse solubility of the mineral grains present has inhibited soil development. The non-carbonate or silicate nature of the bedrock limited the formation of clay size fraction and inhibited the development of mature soils. Typically, Brunisol, Podzolic, Gleysolic, Talus and Peat types of soil occur in the Algonquin-Haliburton region. Podzolic and Brunisolic are the dominate soil types of the region found in zones of good to moderate drainage in gentle to moderately steep slopes. Generally the soils are poorly developed. However, in both types, a leaf litter layer overlies a black, organic-rich "A" layer. This general thin "A" layer (<15 cm) is underlain by a reddish to dark brown "B" horizon which contains more silt and clay than the deeper unweathered "C" horizon. The Podzols, unlike the Brunisols, has a grey, highly leached "Ae" horizon between the "A" and "B" horizons. Brunisolic soil formation generally appears to occur in poorly drained areas which tend not to form the "Ae" horizon or on coarse-grained, well-drained parent material where the "Ae" horizon is also absent. Due to the relative immaturity of the soils, absolute classification is difficult. Tree uprooting in thin overburden also disrupts the soil formation and makes separation of Brunisol and Podzolic soils very difficult.

Gleysolic soil type is found in the extreme south of study in areas of marble bedrock and carbonate-rich till. The "Ae" horizon is mottled and clay accumulation occurs in the "B" horizon. No Gleysolic soils were found in proximity to the watersheds under study.

Talus or "scree" soils are found in association with zones of extremely steep bedrock. Frost shattering and rapid soil creep accumulates debris which exhibits no soil profile, but reflects Podzolic characteristics. Talus is relatively insignificant in the region as a whole.

The three basic sites of organic deposits are:

1. bedrock-restricted pockets, often perched in elevated or ridge areas,
2. depression in glacio-fluvial deposits at least seasonally below the water table, and
3. bedrock-bound elongate valley extensions of existing water-bodies.

The peat deposits adjacent to lakes tend to contain reeds, rushes and clumps of alders in area of prolonged and relatively deep spring flooding. The poorly-drained peat accumulating areas which experience mild seasonal flooding contain Sphagnum and black spruce while the bog areas that are not seasonally flooded have Sphagnum and hemlock. Often this vegetative progression is common in concentric rings around a single bog.

Geochemically, the soil reflects the felsic composition of the parent granite-gneiss bedrock. The lack of carbonate in the regional bedrock setting is reflected in the soils, with the exception of those formed in proximity to marble beds.

The sand-size fraction dominates all soil horizons and is extremely resistant to weathering, limiting the formation of the more chemically active clay size fraction. The soils are very acidic in nature and have a soil pH of less than 4.5 at the surface and increase to just above 5.5 in the "C" horizon, if present.

The organic component of the soils conversely decreases with depth in the soil profile as does the cation exchange capacity of the soils. The total exchangeable bases of the area soils (Jeffries and Snyder 1983) averages ~3.4 meq/100 g of soil in the "A" horizon and falling to 0.8 meq/100 g of soil in the "C" horizon.

The Podzolic and Brunisolic soils of the Algonquin-Haliburton region have considerable cation exchange capacity in the upper horizons; however, in the exchangeable sites the hydrogen ion dominates. The total exchangeable bases decrease with depth; however, the soil pH indicates a general decrease in acidity with depth as the exchangeable sites are dominated by bases rather than the hydrogen ion. The lower total exchangeable bases of the "C" horizon is due to the absence of organic residues, oxides and clay material.

## 13. SURFICIAL GEOLOGY (REGIONAL)

Deposits of the Quarternary glaciation dominate the Algonquin-Haliburton region. The glacial deposits are the ice-contact, fluvial and lacustrine type. Ice-contact type deposits include basal and melt-out "englacial" tills and melt-out kame deposits, generally recognized by poor sorting and the presence of large boulders in the matrix. The fluvial deposits generally consist of the sand and gravel deposited by the meltwaters flowing off the glacier. The size sorting of the fluvial deposits reflects the general inability of the meltwater to move the large boulders more than short distances from the glacier face. The fine silt and clay fraction remain suspended in the outwash rivers are deposited in the deeper glacial lake regions.

Lacustrine deposits generally consist of clays and fine silts deposited in deep water, the amount depending upon the distance from the shore, the water depth and the sediment source. The points of river entry into the glacial lakes were potential delta sites. As a result, wave action, combined with the lateral transport of sediment, formed clean beach sand deposits.

The glacial deposits of the Algonquin-Haliburton area are shown in Chapman (1975). Recent work by the Ontario Geological Survey has provided excellent, detailed information on the Algonquin Park portion of our study area.

## 14. SURFICIAL GEOLOGY (WATERSHED)

### Big Porcupine Lake

The surficial cover in the Big Porcupine catchment (Figure 10, App. 2) consists of mostly thin till and rock ridges which occupies much of the rugged, steeper portion of the watershed (except sub-watershed #2). The ridges of the thin till and rock trend north-east/south-west, parallel to the lineament sets and the strike of the south-dipping bedrock beds. The thin till and rock ridges are commonly broken by elongate ridges of exposed bedrock and lobes of slightly deeper and continuous thin till. The largest areas of exposed bedrock are associated with the felsic intrusion in the southern portion of the watershed. On the gentler slopes there is a minor till plain.

A unique feature of Big Porcupine Lake is the expanse of peat bog, and sand plain complexes in the south-western portion of the watershed. These resulted from a short-term southern drainage route established during the glacial retreat through the watershed. The sand plain contains numerous bogs that are a poorly drained, level valley floor deposit. The major bogs are in slight depressions in the sand plain which narrows to a single strip in the south-west extremity of the watershed.

A small kame complex, to the south of a large bog pond complex, exists in the large south-west lobe of the watershed, also indicating a short-term ice contact southward draining glacial runoff.

### Clear Lake

Thin till and rock ridges dominate the surficial geology of Clear Lake (Figure 13, App. 2). Several small zones of more continuous thin till are west and north of the lake. The sinuous, exposed bedrock areas are generally associated with a biotite gneiss ridge area parallel to the strike of the bedrock and a fault pattern which also strikes in the same direction. Much of the exposed bedrock is along the lake shoreline, resulting from wave erosion of the thin till during periods of high lake level.

Table 4: Surficial geology of the Big Porcupine catchment as a % composition of the Subwatershed

| Surficial[a] Type | 1 | 2 | 3 | 4 | 5 | 6 | Ungauged |
|---|---|---|---|---|---|---|---|
| | | | Subwatersheds | | | | |
| 1 | 3.0 | 0 | 5.5 | 2.2 | 1.7 | 6.7 | 3.24 |
| 2 | 57.0 | 3.6 | 73.4 | 56.5 | 59.7 | 78.6 | 65.6 |
| 2a | 19.9 | 0 | 5.5 | 7.3 | 2.6 | 2.9 | 4.5 |
| 3 | 0 | 94.3 | 3.7 | 14.3 | 17.0 | 0 | 20.5 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 1.0 | 0 | 4.8 | 0 | 2.1 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 1.8 | 2.1 | 1.9 | 4.1 | 3.3 | 0 | 0.2 |
| 7a | 1.0 | 0 | 0.2 | 8.3 | 4.4 | 0 | 0.2 |
| 7b | 0 | 0 | 0 | 0 | 3.6 | 0 | 0.2 |
| Pond | 19.3 | 0 | 9.8 | 7.3 | 2.9 | 11.8 | 0 |

[a] 1 - Exposed bedrock
2 - Thin till and rock ridges
2a - Continuous thin till
3 - Minor till plain
4 - Ice contact kame complex
5 - Outwash sand and gravel
6 - Sand, beach and plain
7 - Peat - sphagnum, conifer
7a - Peat - rushes, reeds, alders
7b - Peat - perennial flooding
Pond - Pond area of subwatershed

Table 5: Surficial geology of the Clear Lake catchment as a % composition of the Subwatershed

| Surficial[a] Type | Whole Watershed |
|---|---|
| 1 | 3.7 |
| 2 | 93.9 |
| 2a | 1.5 |
| 3 | 0 |
| 4 | 0 |
| 5 | 0 |
| 6 | 0 |
| 7 | 0.9 |
| 7a | 0 |
| 7b | 0 |

[a] see Legend on Table 3

Table 6: Surficial geology of the Crown Lake catchment as a % composition of the Subwatershed

| Surficial[a] Type | 1 | 2 | 3 | 4 | 5 | 6 | Ungauged |
|---|---|---|---|---|---|---|---|
| | Subwatersheds | | | | | | |
| 1 | 7.0 | 1.3 | 4.9 | 9.1 | 5.2 | 0.7 | 3.8 |
| 2 | 82.2 | 69.4 | 59.1 | 64.2 | 60.5 | 9.3 | 73.0 |
| 2a | 0 | 12.9 | 25.5 | 26.7 | 14.5 | 0 | 1.9 |
| 3 | 6.4 | 8.5 | 7.9 | 0 | 19.8 | 76.9 | 12.8 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 3.8 |
| 5 | 0 | 2.1 | 0 | 0 | 0 | 0 | 3.7 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0.6 | 5.8 | 0 | 0 | 0 | 0 | 1.0 |
| 7a | 3.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7b | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pond | 0 | 0 | 2.6 | 0 | 0 | 13.1 | 0 |

[a] See legend in Table 3

The only major peat bog is at the extreme south-west corner of the lake. Several small, isolated pockets of peat occurs in the north-east section of the watershed. Clear Lake watershed contains no glacial fluvial deposits.

Crown Lake

Generally, the Crown Lake watershed is covered by thin till and rock ridges (Figure 16, App. 2), with till pockets less than 1 m in depth. The thin till and rock ridges dominate the rugged upland portions of the watershed, in particular the region to the east of the main lake body. The rock ridges, which pierce the thin till cover, strike south-west perpendicular to the gentle south-east dip of the gneissosity of the bedrock. Large exposed bedrock outcrops are found only near the south-west cliff faces whose direction is similar to the major ridges and valleys of the watershed. Organic deposits are found in the numerous circular bogs with one larger ribbon-like bog in the north-east section of the watershed. Generally, the valleys slope sharply to the lake, providing only a few areas of sufficiently poor drainage to contain sites of organic accumulation.

Adjacent to the south edge of Crown Lake's most southerly bog is a deep (~10 m) continuous band of sorted glacial material. This layer completely covers all bedrock up to 15 m above the lake level. There is one sand/gravel pit in the watershed and it is in this area. This pit shows rounded boulders up to 0.5 m in diameter imbricated with a coarse sand. A silt/sandy layer appears frequently on the top of the boulder/gravel/sand complex. Boulders are less frequent west of the pit. Several kettle-like depressions, ~30 m in length and ~6 m deep are also found in this deposit which is devoid of ponds as a result of the permeable nature of the deposit. The deposit follows a contour 15-20 m above the lake surface, reaching several hundred meters into the valley. This valley contains the #5 subwatershed and extends beyond the watershed boundary into the valley to the east which has in it the sand and gravel pit.

Major sand deposits, void of gravel and boulders, occur in the low area connecting the Crown Lake's south basin to the main lake

body, and also inland from the large bog at the north-west of the main Crown Lake basin. The deposits are in the flat terrain rising less than 5 m above the present lake surface. The sand deposits are a result of density sorting of the sand. The deposits are ribbon-like, due to filling of the bedrock valley, but do not show the distinct sand/gravel/cobble beds common in glacial fluvial networks. The sand areas are void of streams and have coniferous vegetation. Several smaller sand deposits occur at valley-shoreline interfaces and are less than 2 m above present lake level.

The central bogs of Crown Lake subwatersheds #1 and #2 also have small sand deposits, which are several meters above the bog plain. The Crown Lake subwatersheds #1 and #2 bog sand wedges occur at points of sharp gradient change and result from sand mobility on the steep slopes and deposition in the relatively flat valley below.

Nunikani Lake

Thin till and rock ridges dominate the Nunikani watershed (Figure 19, App. 2). Lobes of deeper and continuous till are scattered throughout the watershed, although the larger lobes are in the south-central portion of the watershed. A relatively uncommon marble bed, which outcrops south-east of Nunikani's south-east shoreline, contributes a marble component in the matrix of the till. This outcrop affects the overlying area and that south of the bed itself.

The larger peat bogs are near the ponds of the watershed. The largest bog is adjacent to a large pond in the north-eastern section of the watershed.

Bedrock exposures are common throughout the watershed. These outcrops usually have their long axis parallel to the fault of gneissosity strike.

Sand and gravel outwash deposits are found in the north-east corner of the watershed along the narrow bay near the Kennisis River inflow. A smaller outwash deposit is found at the outflow to the major north-eastern pond.

Table 7: Surficial geology of the Nunikani Lake catchment as a % composition of the Subwatershed

| Surficial[a] Type | Subwatersheds 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Ungauged |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.2 | 0 | 0.7 | 0.5 | 0.3 | 2.2 | 0.2 | 0 | 0 | 1.2 | 1.1 |
| 2 | 89.0 | 93.0 | 82.1 | 84.7 | 86.2 | 79.6 | 79.4 | 92.5 | 100 | 79.8 | 89.8 |
| 2a | 10.8 | 7.0 | 17.2 | 4.9 | 11.8 | 2.2 | 3.3 | 6.1 | 0 | 6.5 | 8.6 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0.1 | 1.7 | 4.5 | 0.1 | 1.4 | 0 | 0 | 0.1 |
| 7a | 0 | 0 | 0 | 0.7 | 0 | 0 | 3.7 | 0 | 0 | 0 | 0 |
| 7b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pond | 0 | 0 | 0 | 9.1 | 0 | 10.9 | 13.3 | 0 | 0 | 12.5 | 0 |
| Carbonate[b] | 0 | 0 | 0 | 0 | 0 | 0 | 64.3 | 33.1 | 2.0 | 96.7 | 0.4 |

[a] See legend on Table 3

[b] Carbonate as percent of subwatershed with marble material identifiable in a field sample of surficial material

Sherborne Lake

Thin till and rock ridges with the till normally less than 1 m in depth dominate Sherborne Lake watershed (Figure 22, App. 2)). Many large, exposed bedrock patches occur throughout the west and north sectors of the watershed in association with the ortho-gneiss bedrock type. This section of the watershed also has many peat bogs. The larger bogs connect with the small lakes and major drainage channels in the subwatersheds. Several smaller bedrock pocket bogs are found throughout the watershed.

In the central and eastern portions of the watershed the exposed bedrock is restricted to cliff faces typical of biotite gneiss bedrock regions. Many large lobes of moderately thin and continuous thin till are also common in the biotite gneiss and quartz monzonite bedrock areas. A relatively large minor till plain is found between the north and east arms of Sherborne Lake. The lobes of deeper till are generally elongated in a north/south direction. Peat bogs are rare in this portion of the watershed, since there is sufficient drainage provided by the generally steep gradient of the numerous fault valleys.

There is only a small deposit of outwash sand and gravel in the extreme north of Sherborne's north bog and a small pocket near to the west of the south arm. A sand and gravel deposit is submerged under the southern-most tip of the south arm and thus does not appear on the map.

Table 8: Surficial geology of the Sherborne Lake catchment as a % composition of the Subwatershed

| Sub-watersheds | Surficial Type[a] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 2a | 3 | 4 | 5 | 6 | 7 | 7a | 7b | Pond |
| 1 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 1.15 | 98.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 4.2 | 81.4 | 2.9 | 0 | 0 | 0 | 0 | 0 | 1.3 | 1.1 | 9.1 |
| 4 | 3.3 | 81.9 | 2.8 | 0 | 0 | 0 | 0 | 2.4 | 2.7 | 0 | 6.9 |
| 5 | 2.4 | 93.4 | 2.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.1 |
| 6 | 3.8 | 87.0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 2.3 | 2.2 | 4.3 |
| 7 | 4.5 | 89.0 | 0.8 | 0 | 0 | 0.9 | 0 | 0 | 0 | 3.3 | 1.5 |
| 8 | 0.4 | 79.8 | 3.8 | 16.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0.9 | 63.8 | 3.2 | 30.82 | 0 | 0 | 0 | 0 | 0 | 0 | 1.3 |
| 10 | 3.7 | 85.1 | 4.7 | 0 | 0 | 0 | 0 | 0 | 1.4 | 0 | 5.1 |
| 11 | 0.6 | 81.6 | 6.9 | 0 | 0 | 0 | 0 | 4.3 | 0 | 0 | 6.6 |
| 12 | 0 | 77.9 | 19.6 | 0 | 0 | 0 | 0 | 2.5 | 0 | 0 | 0 |
| 13 | 0.5 | 72.1 | 27.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 80.5 | 0 | 0 | 0 | 0 | 0 | 0 | 8.2 | 0 | 11.3 |
| Ungauged | 1.4 | 89.0 | 1.4 | 1.4 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 |

[a] See legend on Table 3

## 15. SUBWATERSHED DESCRIPTIONS

### Big Porcupine Lake

Big Porcupine Subwatershed #1 is at the northern tip of the Big Porcupine watershed (Figure 8, App. 2). The northern portion of the subwatershed drains directly into Ling Lake. This lake's outflow travels a short distance eastward before turning 90° to the south-west along a fault valley into the northern bay of Big Porcupine Lake. The bedrock type of this subwatershed is undifferentiated biotite gneiss. The dominant surficial type, thin till with rock ridges, surrounds the lake and the main stream. An area of moderate thin till exists in the western portion of the watershed and a small elongated zone to the north-east of Ling Lake.

Big Porcupine Subwatershed #2 is a small, oval-shaped sub-basin, midway along the eastern watershed boundary of Big Porcupine Lake. The bedrock is mainly a north-east/south-west striking biotite gneiss. The surficial cover of Subwatershed #2 consists of a minor till plain, with several small areas of thin but continuous till cover. Peat accumulation and ponds are absent from Subwatershed #2. The main valley of Subwatershed #2 has a low stream channel gradient and gently sloping, till covered flanks.

Big Porcupine Subwatershed #3 is a large, round sub-basin draining north. The subwatershed is centered about a large, north-west/south-west trending, regional fault. This same fault cuts the long axis of Tea Lake, the major waterbody in Subwatershed #3. The radial drainage pattern results in all streams flowing into Tea Lake before flowing northward into the southern tip of Big Porcupine Lake. A small pond on the eastern flank of Tea Lake, flows west into Tea Lake. The north-south trending valleys, south of Tea Lake have a series of narrow valleys with small emphemeral streams and narrow peat bogs with drainage northward into Tea Lake. The western portion of Subwatershed #3 has less of a gradient. Local relief results in several large, rounded peat bogs which drain into Tea Lake. The bedrock is biotite gneiss, generally striking north-south and dipping to the east, and has a large felsic intrusive in the south-east corner. The dominant surficial type is thin till and rock ridges which typically lie on the steep

eastern slopes of the narrow valleys. Many of the western slopes are slightly deeper lobes of moderately thin and more continuous till. Areas of minor till occur in the western portion of the watershed and several are located at the north-eastern portion of the subwatershed. A small lens of outwash sand and gravel occurs at the northern edge of Tea Lake and along both sides of the Tea Lake outflow. The outflow has cut a channel several meters deep through this level deposit.

In Subwatershed #4, two ponds lie in the poorly drained, low gradient portion of the watershed. Drainage is north-eastward from the large hills at the back of the watershed, through the two ponds and into the eastern shoreline of Big Porcupine's southern arm. The bedrock consists of highly granitized gneiss, striking north-east/south-west and dipping to the south-east. The dominant surficial type is thin till and rock ridges, with several lobes of moderately thin till occurring in the western portion of the watershed. The low, rugged terrain in the area of the two ponds is covered with dense coniferous forest. Adjacent to the ponds are reed, rush and alder zones, which flood every spring as the lake level rises. Adjacent to the ponds are black spruce and Sphagnum bogs.

Big Porcupine Subwatershed #5 is the largest of Big Porcupine's subwatersheds. The topography has a massive dome which rises over 100 m along the mid section of the south-east subwatershed boundary. The central portion of the subwatershed is a broad, complex and rugged valley over 1 km in width and extending outside the southern boundary of the subwatershed. The two large ponds in the watershed are located about 1 km apart in a large north-east/-south-west trending fault valley which divides the watershed in half. A second large fault striking north-west to south-east contains the primary stream channel which receives drainage from the outflows of the two major ponds. Three streams, over 1 km in length, drain northward from the southern portions of the watershed and flow into the waterways of the two major fault valleys. A larger stream also drains the large bog area in the extreme north of the subwatershed and flows through several small ponds to the main stream before it flows into the central basin of Big Porcupine Lake. The gradient of the main stream channel, before entering the

lake, is low and results in spring flooding over a large area. A large area adjacent to the lake is poorly drained and there are dense clumps of vegetation with pockets of water between them for 1 km upstream from the lake. The 6 m wide main channel meanders through this bog area before entering the lake. The subwatershed has a north-east/south-west striking, southward dipping undifferentiated biotite gneiss. The large dome along the south-east boundary of the watershed is a felsic intrusive plug. The gneiss beds become more granitic and less metasedimentary near the granitic mass. The resistant nature of the granitic plug resists erosion, creating this large dome which rises over 100 m above the surrounding topography. The dominant surficial type is thin till and rock ridges which occupy a large portion of the main valley. Several areas of slightly deeper, continuous till are found on the south-east slopes of the larger ridges. Minor till plains occur in the extreme north-west of the watershed and in portions of the north-eastern lobe. The minor till areas are generally in the higher, gentle sloping regions of the watershed.

Big Porcupine's Subwatershed #5 is unique among the subwatersheds because of the major sand deposits in the deeper north-east/-south-west trending valley floors. The sand is free of large pebbles and boulders implying significant water-sorting during deposition. The sand is, in most cases, adjacent to the waterbodies and may be assumed to extend under the major bogs and poorly drained areas in the watershed. Generally, the sand deposits are wider in the north but become narrower as the valley narrows to the south. The sand in the valleys affects drainage within the subwatershed. The stream channels are angular, dendritic, and bedrock-controlled at high elevation. Meanders exist on the low-gradient sand deposits. These deposits contain swamp-like areas of rush and reed, Sphagnum spruce bogs, as well as the immense flooded main bog adjacent to the lake body. Exposed bedrock occurs along major cliff faces, on the bare ridges in the main sand deposition areas and on the steep sloping areas.

Big Porcupine Subwatershed #6 is north-west of Big Porcupine's central water body. The subwatershed has a north-east/south-west trending valley which is cut by a north-west/south-east trending

fault, resulting in the main stream channel turning 90° to the east and flowing into Big Porcupine Lake. The subwatershed is similar to Subwatershed #4 since two small ponds are surrounded by bogs, thin till and rock ridges. The southern tip of Subwatershed #6 has deeper till relative to the remainder of the subwatershed. Exposed bedrock "ribbons" trend in the same direction as the predominant valley ridge complexes.

Clear Lake

Thin till and rock ridges dominate the surficial geology of Clear Lake (Figure 11, App. 2). Several small zones of more continuous thin till occur to the west and north of the lake. The sinuous, exposed bedrock areas generally associate with a biotite gneiss ridge area. They are parallel to the strike of the bedrock and a fault pattern which also strikes in the same direction. Many of the exposed bedrock outcrops are associated with the lake shoreline, representing wave erosion of the thin till during periods of high lake level.

The only peat bog near the lake is at the extreme south-west corner of the lake. Several small, isolated pockets of peat occur in the north-east section of the watershed.

The Clear Lake watershed contains no glacial fluvial deposits.

Crown Lake

Crown Lake #1 is the largest of the Crown Lake subwatersheds (Figure 14, App. 2). The main stream results from a combination of two large streams which flow parallel to the Crown Lake shoreline in a south-westerly direction. The two tributaries drain steep-sloping V-shaped valleys, although the gradient of the stream channel is quite low. The western flanks of the V-shaped valleys are gentler than the steep, step-like eastern flanks. The main valley near the lake is occupied by beaver ponds. Rush and alder bogs exist for a distance of over 1 km and often over 100 m in width.

The bedrock of Crown Lake #1 subwatershed strikes south-west parallel to the flow direction of the two main tributaries and dips

south-westward at approximately 30 degrees. The step-like nature of the two western slopes runs the entire length of the watershed and reflects differential glacial erosion and faulting of the bedrock. The dominant surficial cover is thin till and rock ridges with the steep north-western slopes of each "step" being a sinuous rock ridge. The gently south-east slope of each step also contains a pocket of till. The only significant ribbon of peat accumulation is in the central valley of the western tributary. Raised beach sand deposits occur at the point of stream entry into the lake and at the edges of the peat deposit.

Several small sand deposits are found on the central valley floor of the easterly tributary, although they are relatively insignificant in terms of spatial extent. The stream exhibits a meandering pattern on the sand wedge near the lake, unlike the straight channel, where angular bedrock controls the drainage pattern found in the north-west section of the watershed.

The watershed is covered with hemlock and pine. Mixed forests occur in zones of deeper till. Rushes and alders are found in the transitional zone around the beaver ponds. Black spruce dominates in the northern bog area. Rushes and thick alder also dominate the sand wedge found at the stream mouth.

Crown Lake #2 is a subwatershed created by the intersection of several large valleys. The main streams flow directly west into Crown Lake. Smaller tributaries follow the major north-east/-south-west lineament trend. One flows south-west and the other north-east to join the main streams. The stream gradient is highly variable. The central part of the watershed has a gentle slope. The lower and upper reaches of the stream have steep waterfall and cascade regions. The main stream flow is from the western edge of the central bog and is fed by smaller ephemeral streams. The three bogs in the watershed are oval in shape. Two of the three bogs contain the main stream channel while the third bog contains the northern tributary to the central bog.

The main stream follows the bedrock east-west lineament. Two bogs also lie in this probable fault line. The north and south tributaries occupy the bedrock valley which is a continuation of the south-west lineament which contains the Crown #1 tributaries. The gneissosity of the bedrock strike is south-west/north-east while the tributaries flow direction is north and south.

Crown Lake #3 subwatershed drains an elongated area on the eastern shoreline of Crown Lake. The main stream is fed by two major tributaries. The largest tributary flows due north to meet the outflow of a large beaver pond, which drains the northern section of the watershed. This tributary drains a small Sphagnum spruce bog in the extreme south of watershed. The tributary channel is surrounded by thin till and rock ridges with a band of minor till on the east and west boundaries of the subwatershed. The beaver pond drains an area of exposed bedrock, and thin till and rock ridges to the east. It also drains a small area of deep till in the north-west boundary area. The outflow of the beaver pond flows over bedrock for a short distance and meets the north flowing tributary. It then continues a short distance west through an area of thin till and rock ridges to the lake. The bedrock is biotite gneiss with strong south-west striking lineaments and a steplike nature as described in Crown #1.

Crown #4 subwatershed is round in shape with a short, central stream flowing north-east to the lake. The entire watershed is thin till and rock ridges with a zone of deeper and continuous till occurring in the extreme west of the watershed.

The main stream channel of Crown Lake #5 subwatershed strikes north-east with the major tributary joining the main channel from the north. The subwatershed has a V-shaped wedge of deep sediments. No bedrock outcrops are found in this sand, gravel and boulder deposit. The topography is gently rolling before the stream drops about 15 m to the lake. The stream channel is a relatively large V-valley cut to several meters in the deep overburden. The upper reaches of the stream are thin till and rock ridges with the stream bed often flowing over bedrock. A large ribbon of exposed bedrock strikes parallel to the main stream channel near the south-east boundary of the watershed.

Crown Lake #6 subwatershed is round in shape and is at the north-western corner of the lake. Several ephemeral streams drain from the north and west, into a large central beaver pond. The open water part of the pond is surrounded by a collar of rushes and alders. Conifers line the shore of the pond. The pond outflows to the west in a series of small cascades cut to the bedrock. The

overburden is thick throughout the subwatershed especially in the beaver pond areas. The ephemeral streams have not cut through the deep till to the bedrock. The perennial outflow from the beaver pond has cut through the several meters of till to the bedrock. A bedrock cliff on the east shore of the pond is the only significant bedrock outcrop in the near-water area. Mature hardwoods dominate the gentle slopes. Conifers, mainly hemlock and spruce, dominate the near-water area.

Nunikani Lake

Nunikani (Fig. 17, App. 2) subwatershed #1 is a small, steep sloping, V-shaped valley. This eastern subwatershed has biotite gneiss bedrock with an extreme western ridge of quartz monzonite. The surficial cover consists of thin till and rock ridges with several small areas of exposed bedrock. The till is more continuous in the upstream portion of the central valley.

Nunikani Subwatershed #2 is similar to Nunikani Subwatershed #1, except that the area of continuous till is nearer the lake shoreline.

Nunikani Subwatershed #3 stream flows east before turning north then flows into the east arm of Nunikani Lake. Thin till dominates the surficial deposit while the bedrock is quartz monzonite. The eastern portion of the basin is biotite gneiss.

Nunikani Subwatershed #4 is the largest (2.14 $km^2$) subwatershed. The dominate bedrock type is biotite gneiss, with a small section of quartz monzonite which occurs in a north-south striking band near the eastern tip of Nunikani Lake's east arm. This first order stream drains north-east/south-west trending fault valley as the outflow of a large pond centrally located in the valley. A large second order stream flows east into a large pond then continues east along the fault valley to the east tip of Nunikani's eastern arm. The main valley of this stream is geologically related to the eastern arm of Nunikani Lake. The dominant surficial type is thin till and rock ridges. The till is more continuous and thicker in several lobes located in the southern half of the watershed. The gradient of the stream valley of Subwatershed #4 is distinctly less than that of the three previously described subwatersheds.

Five small areas of peat are also present. The peat accumulation is associated with streams or ponds in most cases. Exposed bedrock usually appears in short ribbon-like bands, generally reflecting the north-east/south-west and north-south fault and bedrock gneissosity strikes. A second set of east-west trending bedrock "ribbons" are situated on either side of the main stream channel.

Nunikani Subwatershed #5 is an elongated east-west striking watershed which drains into the north shore of the north arm of Nunikani Lake. The bedrock is quartz monzonite in the western half of the watershed and biotite gneiss in the east. Thin till and rock ridges dominate several lobes of more continuous and deeper till which also occur in the basin. Several small peat bogs occur along the southern subwatershed as do several small areas of exposed bedrock.

Nunikani Subwatershed #6 is a large oval-shaped subwatershed (0.81 $km^2$) with a large pond located along the eastern subwatershed boundary. The southerly portion of the watershed has biotite gneiss as its bedrock type, while the northern section is quartz monzonite. Thin till and rock ridges dominate the surficial cover. Three small areas of thicker and more continuous till lie along the northern subwatershed boundary. Nunikani watershed's largest peat bog is adjacent to the western shore of the large pond. On the eastern side of the large pond are several large, exposed bedrock areas. To the west of the large pond is a multitude of smaller "ribbon-like" exposed bedrock areas.

The outflow from the large pond flows over a glacial outwash sand and gravel deposit. This short distance of stream length is the only portion of stream in all of Nunikani watershed where the bedrock does not control the stream channel, with the exception of the bog areas. The deep level deposit also induces several stream meanders. This stream appears to be the only one with significant bed load. The result of the stream channel erosion of this deposit is a small sand and gravel delta in the lake at the stream mouth.

Nunikani Subwatershed #7 is the largest subwatershed east of Nunikani Lake. The main stream channel flows north-east through a series of bogs, in a relatively narrow valley, before flowing north-west a short distance in the north arm of Nunikani Lake. The dominate bedrock type is biotite gneiss; however, a relatively rare

marble bed, 3-5 m wide, cuts through the watershed for just under a km. The main marble bed is also part of the thin marble interbeds in the biotite gneiss immediately surrounding the main marble bed. Thin till is the major surficial deposit of Nunikani Subwatershed #7. Unlike Subwatersheds 1-6, marble pebbles and boulders are present south of the marble bedrock bed. Several small pockets of deeper, more continuous till are found in the watershed. Areas of exposed bedrock are numerous but represent a small area. The main valley, containing the main stream channel, is the site of a string of bogs and shallow beaver ponds, extending from the mouth of the stream almost to the southern tip of the watershed.

Nunikani Subwatershed #8 is a small (0.05 $km^2$) subwatershed, lying between Subwatershed #7 and the north arm of Nunikani Lake. The bedrock is biotite gneiss with a thin (3-5 m) marble bed running the length of the south-eastern subwatershed boundary. Several smaller marble interbeds, within the gneiss, occur in proximity to the main bed. Thin till and rock ridge dominate the steep north-facing subwatershed. One small zone of peat deposition, a small area of more moderate till depth and several areas of exposed bedrock, make up the remainder of the surficial cover. Along the south-east subwatershed boundary is a significant amount of marble mixed with a predominately silicate based till.

Nunikani Subwatershed #9 is an extremely small (0.05 $km^2$), steep watershed draining the eastern flank of Nunikani Lake. The bedrock type is biotite gneiss with an extremely short section of marble and associated marble biotite gneiss interbeds occurring at the intersection of the boundaries of subwatersheds #7, #9, and #10. Thin till and rock ridges dominate, but several exposed bedrock areas are also present. The presence of carbonate in the till, assuming a south-west/south-east ice direction, is limited to the immediate area of the marble and interbedded marble outcrop.

Nunikani Subwatershed #10 stream outflows from a large, central pond, along a fault to the southern tip of Nunikani Lake. The bedrock type is biotite gneiss with a thin marble bed traversing the subwatershed in a north/south direction, meeting the central pond at its outflow. If glacial movement was in a southerly direction then the marble bed is likely dispersed through the subwatershed. It would probably be most concentrated in the till over and

adjacent to the bedrock bed. The marble is also due to the strike of the marble bed which is enriched in the till near the outflow of the major pond. The dominate surficial type is thin till and rock ridges. The areas of slightly deeper and more continuous till are small and in the more elevated regions near or in the subwatershed boundary. Many tiny "ribbon-like" areas of exposed bedrock occur throughout the watershed and have a long axis parallel to the major north-east/south-west fault containing the southern and northern arms of Nunikani Lake.

Sherborne Lake

Sherborne Subwatershed #1 contains a small 1st order stream which flows southward into the south arm of Sherborne Lake near the natural outflow (Figure 20, App. 2). The bedrock is ortho-gneiss, with several small outcrops on the western flank of the stream channel. The surficial cover is thin till and rock ridges. Sherborne Subwatershed #2 has a main valley which is narrower and longer than the one in Subwatershed #1.

Sherborne Subwatershed #3 is a large, relatively elongated sub-basin. This stream flows several km southward along a major fault before entering the east arm of Sherborne Lake. The major fault valley contains three large waterbodies including Little Avery Lake, that lie equidistant along the length of the main stream channel. The largest of these is Avery Lake which lies to the west of the main stream valley, along an east-west trending fault line. The subwatershed bedrock type is ortho-gneiss. The surficial cover is thin till and rock ridges. Several lobes of deeper, more continuous thin till flank Avery Pond in the northern section of the subwatershed. Many expansive exposed bedrock areas are scattered throughout the watershed. Peat is found in several deposits along the main stream channel and adjacent to the shallow ponds area along the eastern tributary.

Sherborne #4 is 0.428 km² in size. The main stream channel of Subwatershed #4 originates from a bog located at the western extreme of sub-basin and flows about 400 m north-east before turning 90° to the south-east and then flows into the main body of Sherborne Lake. The main stream valley contains three ponds,

although these are much smaller and shallower than those in Subwatershed #3. The bedrock is ortho-gneiss with the two largest areas of exposed bedrock at the extreme western boundary of the subwatershed. Thin till and rock ridges dominate the remainder of the subwatershed, with a section of slightly deeper, more continuous till south of the main stream at the front of the sub-basin.

The main stream of Subwatershed #5 flows along a south-east/-north-west trending fault valley entering Sherborne's large northern bay on the western shore. Orley Lake occupies a large portion of the central valley. Most of the subwatershed, including all of Orley Lake, lies on ortho-gneiss bedrock, but a small portion of the subwatershed, within 150 m of the lake, has biotite gneiss bedrock. The spatially dominate surficial type is thin till and rock ridges with a slightly deeper thin till section in the south- eastern region of the subwatershed. Exposed bedrock area exist along the shoreline of Orley Lake. There are no peat deposits in the watershed.

Sherborne Subwatershed #6 is the largest subwatershed of Sherborne Lake. The main third order stream channel flows southward along a large fault valley. The two main tributaries in the south half of the subwatershed initially flow northward before turning and flowing southward into the main stream. The more northerly tributaries drain swamp and peat bog areas and flow southward to the main stream. The two dominant bedrock types found in Subwatershed #6 are ortho-gneiss in the western and northern portions and biotite gneiss in the eastern and southern portions. A large block of biotite gneiss occurs within the ortho-gneiss near the western boundary of the watershed. A gabbro plug also occurs in the biotite gneiss, along with an ortho-gneiss zone near the point the main stream enters the north tip of Sherborne Lake. Thin till and rock ridges dominate the surficial geology of Subwatershed #6. Exposed bedrock areas are numerous and areas of moderately thin till are extremely rare. The exposed bedrock areas appear to have a north-south trend. There are many ponds and swamps in the valleys; some exceed several hundred meters in length. The two largest peat deposits are also found in the main valley of Subwatershed #6.

The main first order stream of Subwatershed #7 flows south-west along a fault valley into the eastern side of Sherborne Lake's northern bay. The subwatershed bedrock is entirely biotite gneiss. The surficial type is thin till and rock ridges with numerous small exposed bedrock outcrops. One small area of slightly deeper thin till exists to the south of the main stream. A small level wedge of outwash sand and gravel is at the point where the main stream enters Sherborne Lake. The deposit rises several meters above the present lake level. The stream channel has cut a 1 m deep channel through the deposits.

Sherborne Subwatershed #8 is a small sub-basin. The main stream flows northward into the southern extremity of Sherborne's north bay. The bedrock composition is biotite gneiss for the entire watershed, except for a few small exposed bedrock areas. The subwatershed is entirely thin till and rock ridges. A zone of moderately thin till extends from midway along the northern subwatershed boundary into the central basin.

Sherborne Subwatershed #9 has a main stream which flows southward into the east arm of Sherborne Lake. Biotite gneiss bedrock is common throughout the entire subwatershed. The surficial composition of Subwatershed #9 is somewhat unique in that a substantial minor till deposit occurs in the basin. The western portion of the subwatershed has much deeper and continuous till cover than the other Sherborne subwatersheds. Thin till and rock ridges dominate the eastern portion of the watershed, with numerous exposed bedrock areas. Several small peat areas also lie in the main valley.

Sherborne Subwatershed #10 is a large, two-lobed basin. The main valley stretches north-east from Sherborne's eastern bay along a major fault line. The north-eastern lobe contains a small pond which outflows to the south-east into the main drainage valley. The main valley of the subwatershed is composed of quartz monzonite bedrock. The north-western lobe is of biotite gneiss to the north of the small pond. The main surficial type is thin till and rock ridges with several zones of slightly deep and more continuous till cover. Two small areas of peat occur around a small pond in the extreme back of the watershed.

Sherborne Subwatershed #11 lies to the east of the lake's extreme easterly arm. Drainage from part of the watershed accumulates in a small pond at the back of the watershed before flowing south-westward into Sherborne Lake. The southern valley drains into a long narrow peat bog, before flowing north into the main stream channel. The contact between the quartz monzonite bedrock to the north and biotite gneiss to the south runs south-west to north-east in proximity to the main stream channel. The dominate surficial type is thin till and rock ridges with numerous bedrock outcrops occurring along the main stream and around the small pond. Two areas of deeper and more continuous thin till are in the subwatershed; one is in the extreme north and the other is in the extreme south. The southern section of the subwatershed includes a long, relatively thin peat accumulation.

Sherborne Subwatersheds #12 and #13 are elongate in shape, stretching north-eastward from midway along Sherborne's southern arm. Both subwatersheds drain areas of biotite gneiss with extreme gradients. The stream falls over 30 m in a relatively short run to Sherborne Lake. The subwatersheds are covered by thin till and rock ridges, although both have zones defined as moderately thin till. The only small peat pocket occurs in Sherborne #12 subwatershed. Several small patches of exposed bedrock occur in the steep parts of the subwatershed near the lake.

Sherborne Subwatershed #14 is a small basin draining north. The ortho-gneiss subwatershed is cut by a north-south trending fault containing the main stream channel. Thin till and rock ridges cover the entire watershed with several areas of exposed bedrock.

# 16. RELATIONSHIPS BETWEEN GEOCHEMISTRY AND SURFACE WATER CHEMISTRY

Lake and stream chemistry reflect the modification of atmospheric acids and oxidants by lithological materials. The dissolution of lithological material falls into the three categories of congruent dissolution, incongruent dissolution, and redox reactions. Congruent dissolution is associated with the consumption of carbonates, while the incongruent dissolution is typified by the weathering of silicate minerals and the production of clay minerals. Both types increase the pH of the solvent by the creation of the bicarbonate ion. Generally, incongruent dissolution dominates in carbonate-rich lithologic systems and congruent dissolution in (non-carbonate) silicate systems. The redox reactions which are capable of producing a strong acid solution are generally limited to the weathering of sulphide deposits and thus most common in areas of mining activity.

The Algonquin-Haliburton region is underlain by silicate lithology. Areas of carbonate-dominated weathering in the Algonquin-Haliburton region occurs in proximity to the massive marble beds of the Carnarvon-Eagle Lake corridor and isolated, thin, impure marble beds as found in the Big Hawk-Nunakani watersheds.

Congruent carbonate dissolution may also be significant in the deeper, relatively unweathered deposits; however, further investigation is required to determine the degree of carbonate participation in the deep surficial deposits. The kinetics of acid neutralization by silicate material are enhanced by the increased surface area of smaller grain sizes. The coarse-grained surficial material of the Algonquin region has decreased neutralization ability because of the small contribution of clay-sized particles to the surficial deposits. A second factor, crucial to the neturalization of acidic precipitation, is the contact time of the solution and the lithology. The longer periods of solution-lithology contact time increase the alkalinity of the effluent. Increasing groundwater contribution will result in increasing alkalinity in the associated streams and lakes.

The organic-rich bogs and swamps tend to have natural pH of 4.0 to 5.0 due to the humic and fulvic acids generated in these

environments. The similarity of the natural equilibrium acidity of these waters with the incident precipitation of the Algonquin-Haliburton region suggests the zones of peat accumulation shift the equilibria of the effluent, but does not significantly raise the pH.

The mineral soils in the Algonquin-Haliburton area are mostly acidic Podzolic and Brunisolic types. The pH of true soils in the weathered upper horizons are generally less than 4.5 and the stronger the salt solution used, the lower the resultant soil pH. The surplus of hydrogen ions in the upper soils horizon limits neutralization of acidic precipitation in this zone. The relatively unweathered "C" horizon will potentially increase the effluent alkalinity relative to the overlying hydrogen saturated upper horizons.

In summary, acidic surface water is associated with the following watershed and subwatershed characteristics:

- reduced groundwater role
- shallow soils with no "C" horizons or shallow surficial deposits
- steep gradient, increased surface runoff
- increasing area of peat accumulation
- insignificant carbonate material present
- increasing mineral grain size
- increasing exposed silicate bedrock

17. STREAMWATER CHEMISTRY

1. Big Porcupine

Five of the six inflows of Big Porcupine Lake (Table 9) had pH of 6.00 or less and total inflection point alkalinities of less than 1.0 mg/L in both the spring and fall sampling periods. The exception, Big Porcupine #2, had a spring pH of 6.23 and a total inflection point alkalinity of 3.79. The high alkalinity and pH of Big Porcupine #2 results from the relatively deep, minor till plain which covers most of the #2 subwatershed. The Big Porcupine outflow had a pH of 5.94 in the spring sample and a slightly higher fall pH of 6.19. The total inflection point alkalinity (TIP) showed a similar trend, with a spring TIP of 0.91 and a fall value of 2.02 mg/L as $CaCO_3$. The depressed pH and alkalinity of the Big Porcupine outflow in the spring probably resulted from acidic snowmelt inputs to the lake during this period.

Streams #4 and #5 had the highest colour as a result of major peat bogs. The lowest colour value was found in the spring sample from Big Porcupine stream #2. The absence of bogs and the presence of a relatively deep surficial cover may explain the low colour of this stream. Porcupine #5 is much larger and of higher colour than the other inflows. The conductivity is consistent between the spring and the fall sampling and typical for non-carbonate Precambrian lakes in the Algonquin-Haliburton region.

Calcium and magnesium values were similar among the Big Porcupine streams. The slightly higher values for stream #2 reflect the effect of the deeper surficial cover found in subwatershed #2 on the stream chemistry. The sodium and potassium values of stream #2 were also higher than the other five streams while the chloride values were relatively low.

The sulphate values ranged from 6.54 to 10.83 mg/L for the Big Porcupine Lake streams. The individual streams showed some variation between the spring and fall samplings; however, the outflow value varied by less than 0.5 mg/L.

Table 9: Chemistry of Big Porcupine Lake inflows and outflow

| Chemical Parameter | Inflow 1 | 2 | 3 | 4 | 5 | 6 | Outflow |
|---|---|---|---|---|---|---|---|
| | | | May 1983 | | | | |
| pH | 5.38 | 6.23 | 5.42 | - | 5.45 | 5.50 | 5.94 |
| Alkalinity | 0.26 | 3.79 | 0.27 | - | 0.66 | 0.24 | 0.91 |
| Colour | 26 | 16 | 17 | - | 82 | 23 | 24 |
| Cond | 29 | 36 | 26 | - | 26 | 24 | 25 |
| Ca | 2.5 | 3.4 | 2.3 | - | 2.5 | 2.1 | 2.3 |
| Mg | 0.58 | 0.90 | 0.56 | - | 0.56 | 0.52 | 0.56 |
| Na | 0.80 | 0.90 | 0.50 | - | 0.80 | 0.65 | 0.65 |
| K | 0.48 | 0.56 | 0.36 | - | 0.38 | 0.40 | 0.32 |
| Cl- | 0.30 | 0.25 | 0.25 | - | 0.20 | 0.26 | 0.29 |
| $SO_4$ | 8.11 | 8.73 | 7.52 | - | 6.99 | 6.69 | 6.99 |
| Fe | 0.035 | 0.020 | 0.105 | - | 0.365 | 0.090 | 0.050 |
| Mn | 0.010 | 0.004 | 0.065 | - | 0.035 | 0.015 | 0.009 |
| DOC | 3.5 | 3.2 | 3.0 | - | 6.3 | 3.6 | 3.3 |
| Silicates | 1.93 | 3.02 | 1.46 | - | 0.85 | 1.51 | 1.50 |
| | | | Nov 1983 | | | | |
| pH | 5.54 | - | 5.72 | 4.67 | 4.87 | 6.00 | 6.19 |
| Alkalinity | 0.30 | - | 0.76 | -1.06 | -.38 | 1.63 | 2.02 |
| Colour | 25 | - | 19 | 96 | 70 | 47 | 24 |
| Cond | 28 | - | 27 | 41 | 39 | 25 | 26 |
| Ca | 2.3 | - | 2.2 | 2.7 | 3.1 | 2.0 | 2.3 |
| Mg | 0.60 | - | 0.56 | 0.80 | 0.86 | 0.60 | 0.62 |
| Na | 0.65 | - | 0.60 | 0.65 | 1.00 | 0.70 | 0.60 |
| K | 0.30 | - | 0.40 | 0.38 | 0.42 | 0.48 | 0.36 |
| Cl- | - | - | 0.68 | - | 0.84 | 0.35 | 0.62 |
| $SO_4$ | 8.00 | - | 7.93 | 8.89 | 10.83 | 6.54 | 7.38 |
| Fe | 0.060 | - | 0.330 | 0.210 | 0.260 | 0.230 | 0.355 |
| Mn | 0.010 | - | 0.091 | 0.041 | 0.067 | 0.024 | 0.067 |
| DOC | 3.5 | - | 3.3 | 10.0 | 8.5 | 5.7 | 3.3 |
| Silicates | 1.38 | - | 1.35 | 0.95 | 2.43 | 1.26 | 1.10 |

Note: All parameters in mg/L except pH, TIP (mg of $CaCO_3$/L), Colour (hazen units), Conductivity ($\mu S/cm^{-1}$)

The iron and manganese values showed considerable variation both between streams and between the sampling periods. Generally the iron values were higher in the fall than the spring with the exception of stream #5. This may be the result of simple dilution by the higher spring flow rates. The massive bogs of stream #5 may simply be less affected by the increased flushing rates of the spring season. The outflow also showed an increase in the fall iron value as four of the five inflows had values over 0.2 mg/L.

The highest DOC values were found in inflows #4 and #5 which also had the highest colour of the six inflows. The most substantial peat bogs are in the same subwatersheds and the leaching of organic material from the peat zones is the probable source of the dissolved organic carbon.

2. Clear Lake

The outflow chemistry (Table 10) of Clear Lake was typical of a very dilute oligotrophic Shield lake. The Clear Lake outflow had low alkalinity in the spring and in the fall. The low colour values demonstrated that wetlands were unimportant in the watershed. The Ca, Mg, Na and K values were also low, reflecting the scarcity of surficial cover and the absence of carbonate material in both the overburden and bedrock (chloride was also low). The remaining ions were also low with the exception of sulphate which exceeded 8 mg/L in both the spring and the fall.

Table 10: Chemistry of the outflow of Clear Lake

| Chemical Parameter | May 83 | Nov 83 |
|---|---|---|
| pH | 5.76 | 5.38 |
| Alkalinity | 0.39 | 0.03 |
| Colour | 7 | 4 |
| Cond | 26 | 28 |
| Ca | 2.3 | 2.4 |
| Mg | 0.50 | 0.60 |
| Na | 0.30 | 0.50 |
| K | 0.30 | 0.38 |
| Cl- | 0.40 | 0.40 |
| $SO_4$ | 8.13 | 8.62 |
| Fe | 0.015 | 0.075 |
| Mn | 0.013 | 0.015 |
| DOC | 1.5 | 4.0 |
| Silicates | 0.36 | 0.52 |

Note: All parameters in mg/L except pH, TIP (mg of $CaCO_3$/L), Colour (hazen units), Conductivity ($\mu S/cm^{-1}$)

## 3. Crown Lake

The streams of Crown Lake (Table 11) were dilute and had moderate to low alkalinities. The stream spring chemistry exhibited lower pH, alkalinity, colour, Ca, Mg, $SO_4$, Fe, Mn, DOC and silicate values than the fall values. The lower pH and total inflection point alkalinity probably resulted from acidic snowmelt. The low values of the other parameters were probably caused by dilution since a large volume of water flushed through the subwatershed system in the spring.

The Crown Lake stream alkalinity ranged between -4.24 and 2.13 (mg of $CaCO_3$/L) and the pH ranged between 4.17 and 5.85. The inflection point alkalinity of Crown Lake streams #5 and #6 exceeded 1.0 (mg $CaCO_3$/L). A similar grouping based on pH is evident with only Crown streams #5 and #6 having pH values greater than 5.5 in both sampling. The surficial geology of the higher alkalinity and pH group is not dominated by thin till and rock ridges like the low alkalinity and pH group. Crown Subwatershed #5 has a deep, kame complex in the downstream portion of the watershed and Crown Lake Subwatershed #6 has a deep minor till plain cover over one-half of the watershed. The water colour generally increased with the percentage of peat and beaver pond area, and the clearest stream, Crown #5, has no bog area present. Sulphate showed little variation between Crown Lake streams, with the exception of the low value for Crown #5. This probably results from the absence of bogs and deep kame complex in Crown Stream #5. These same factors may explain the same low DOC value for this stream. The silicate values appeared lower for Crown #3 and #6 streams, possibly due to the large ponds with low flushing rates located near the lake shoreline in both subwatersheds.

Table 11: Chemistry of Crown Lake inflows and outflow

| Chemical Parameter | Inflow 1 | 2 | 3 | 4 | 5 | 6 | Outflow |
|---|---|---|---|---|---|---|---|
| | | | May 1983 | | | | |
| pH | 4.17 | 5.10 | 5.22 | 4.90 | 5.63 | 5.85 | 5.64 |
| Alkalinity | -4.24 | -.21 | -.10 | -.60 | 1.40 | 1.26 | 0.38 |
| Colour | 36 | 58 | 29 | 48 | 5 | 40 | 12 |
| Cond | 72 | 30 | 28 | 32 | 32 | 24 | 25 |
| Ca | 2.5 | 2.3 | 2.3 | 2.7 | 2.5 | 2.1 | 2.1 |
| Mg | 0.50 | 0.52 | 0.50 | 0.56 | 0.82 | 0.48 | 0.50 |
| Na | 0.65 | 0.80 | 0.70 | 0.65 | 0.70 | 0.75 | 0.60 |
| K | 0.30 | 0.38 | 0.36 | 0.30 | 0.72 | 0.50 | 0.34 |
| Cl- | 0.20 | 0.20 | 0.25 | 0.30 | 0.25 | 0.25 | 0.32 |
| $SO_4$ | 7.68 | 8.10 | 8.44 | 8.63 | 8.56 | 6.17 | 7.41 |
| Fe | 0.180 | 0.070 | 0.035 | 0.025 | 0.005 | 0.065 | 0.040 |
| Mn | 0.021 | 0.0310 | 0.020 | 0.030 | 0.006 | 0.007 | 0.006 |
| DOC | 4.1 | 5.4 | 3.9 | 4.8 | 1.7 | 4.1 | 2.2 |
| Silicates | 1.39 | 1.46 | 0.81 | 1.50 | 2.50 | 0.38 | 0.38 |
| | | | Nov 1983 | | | | |
| pH | 5.33 | 4.91 | 5.29 | 5.03 | 5.60 | 5.81 | 5.57 |
| Alkalinity | 0.49 | 0.37 | 0.24 | -.10 | 2.03 | 2.13 | - |
| Colour | 11 | 88 | 45 | - | 6 | 76 | 29 |
| Cond | 34 | 42 | 33 | - | 35 | 22 | 30 |
| Ca | 2.9 | 3.9 | 2.7 | 3.6 | 2.6 | 1.9 | 2.3 |
| Mg | 0.64 | 0.88 | 0.66 | 0.80 | 0.94 | 0.48 | 0.52 |
| Na | 0.70 | 0.70 | 0.55 | 0.60 | 0.55 | 0.65 | 0.35 |
| K | 0.46 | 0.34 | 0.34 | 0.16 | 0.66 | 0.50 | 0.26 |
| Cl- | 0.59 | 0.52 | 0.41 | 0.39 | 0.35 | 0.20 | 0.35 |
| $SO_4$ | 9.42 | 12.31 | 9.27 | 11.25 | 9.60 | 4.67 | 8.74 |
| Fe | 0.240 | 0.160 | 0.115 | 0.100 | 0.020 | 0.260 | 0.005 |
| Man | 0.045 | 0.067 | 0.055 | 0.054 | 0.014 | 0.021 | 0.010 |
| DOC | 5.5 | 8.9 | 6.1 | 7.3 | 2.1 | 7.1 | 1.3 |
| Silicates | 2.98 | 3.43 | 2.22 | 3.14 | 3.07 | 1.38 | 0.33 |

Note: All parameters in mg/L except pH, TIP (mg of $CaCO_3$/L), Colour (hazen units), Conductivity (µmoles cm²)

## 4. Nunikani Lake

The main inflow to Nunikani Lake is the large Kennisis River which minimizes the affects of the other ten streams on the chemistry of Nunikani Lake and its outflow (Table 12). The inflows of Nunikani Lake are dilute and have moderate to low alkalinities. The spring stream chemistry exhibited lower pH, alkalinity, colour, Ca, Mg, $SO_4$, Fe, Mn, DOC and silicate values than the comparable fall values, although exceptions were evident. The lower pH and total inflection alkalinity in spring was probably due to acidic snowmelt.

The Nunikani stream alkalinities ranged from 0.20 to 14.2 (mg of $CaCO_3$/L) and the pH ranged from 5.41 to 6.72. Based on pH, the Nunikani streams fall into two groups, one having pH less than 6.0, and the other with pH greater than 6.5. Similarly, the same groups may be separated in terms of alkalinity into those having alkalinities less than one and those greater than five. The low pH alkalinity group includes streams numbers 1 to 6, and the high pH alkalinity group includes subwatersheds numbers 7, 8 and 10. The first group is geologically dominated by thin till and rock ridges and the low pH and alkalinity (see Section 16. GEOCHEMISTRY AND SURFACE WATER). The second group has significant areas of marble bedrock within the boundaries of the watersheds. The marble is disseminated in the till to the south of the bed by glacial abrasion; as a result this very thin bedrock layer has a strong influence on the resultant surface water chemistry. Stream #7 which had the highest pH and alkalinity in both samplings also has the greatest exposure of the marble bedrock bed in its subwatershed. The bulk of its area lies to the south of the bed, making ideal conditions of dispersion of the marble in the till.

Stream #9 and the Kennisis River have chemistries between those of the two groups described above. Subwatershed #9 has some marble bedrock; as a result the stream chemistry is between the silicate and marble-influenced watersheds. The Kennisis River drains a large watershed area. The calcium values are high in the subwatersheds with marble present. The calcium and magnesium values were higher in the spring sampling as the high

Table 12: Chemistry of Nunikani Lake inflows and outflow

| Chemical Parameter | Inflows 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Outflow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May 1983 | | | | | | | | | | | | |
| pH | 5.88 | 5.87 | 5.77 | 5.41 | 5.78 | 5.29 | 6.62 | 6.22 | 6.20 | 6.65 | | 6.32 |
| Alkalinity | 0.67 | 0.47 | 0.64 | 0.20 | 0.47 | 0.16 | 8.18 | 4.09 | 3.08 | 5.07 | | 1.38 |
| Colour | 15 | 22 | 7 | 27 | 8 | 20 | 45 | 22 | 72 | 14 | | 9 |
| Cond | 27 | 27 | 30 | 26 | 28 | 25 | 39 | 37 | 36 | 36 | | 29 |
| Ca | 2.5 | 2.4 | 2.8 | 2.4 | 2.5 | 2.3 | 5.6 | 3.6 | 3.8 | 4.6 | | 2.5 |
| Mg | 0.44 | 0.50 | 0.48 | 0.58 | 0.44 | 0.42 | 0.52 | 1.02 | 0.96 | 0.58 | | 0.56 |
| Na | 0.35 | 0.35 | 0.35 | 0.35 | 0.40 | 0.35 | 0.30 | 0.35 | 0.65 | 0.30 | | 0.50 |
| K | 0.56 | 0.62 | 0.56 | 0.46 | 0.52 | 0.34 | 0.42 | 1.40 | 0.92 | 0.32 | | 0.50 |
| Cl- | 0.15 | 0.13 | 0.18 | 0.24 | 0.26 | 0.16 | 0.17 | 0.30 | 0.21 | 0.18 | | 0.31 |
| $SO_4$ | 7.85 | 8.10 | 8.16 | 7.71 | 8.54 | 6.85 | 7.05 | 9.40 | 9.13 | 8.09 | | 7.91 |
| Fe | 0.015 | 0.015 | 0.005 | 0.085 | 0.015 | 0.075 | 0.255 | 0.020 | 0.100 | 0.080 | | 0.20 |
| Mn | 0.004 | 0.006 | 0.003 | 0.041 | 0.007 | 0.022 | 0.040 | 0.003 | 0.021 | 0.029 | | 0.10 |
| DOC | 2.5 | 3.0 | 1.8 | 3.5 | 2.0 | 3.0 | 5.2 | 4.0 | 6.9 | 3.5 | | 2.3 |
| Silicates | 1.55 | 1.21 | 2.23 | 1.18 | 2.10 | 0.88 | 0.60 | 1.77 | 2.03 | 1.02 | | 1.03 |
| Nov 1983 | | | | | | | | | | | | |
| pH | 5.56 | 5.40 | 5.49 | 5.72 | - | 5.60 | 6.76 | 6.53 | 5.80 | 6.72 | 6.16 | 6.45 |
| Alkalinity | 0.59 | 0.57 | 0.53 | 0.70 | - | 0.73 | 14.22 | 11.79 | 1.61 | 6.26 | 1.80 | 2.20 |
| Colour | 7 | 19 | 7 | 16 | - | 17 | 54 | 18 | 50 | 13 | 7 | 13 |
| Cond | 38 | 40 | 34 | 28 | - | 26 | 45 | 76 | 101 | 34.3 | 30.2 | 27 |
| Ca | 3.9 | 3.8 | 3.3 | 2.3 | - | 2.2 | 7.3 | 10.7 | 10.7 | 4.8 | 2.6 | 2.4 |
| Mg | 0.66 | 0.78 | 0.56 | 0.64 | - | 0.46 | 0.64 | 0.92 | 2.68 | 0.58 | 0.60 | 0.62 |
| Na | 0.50 | 0.50 | 0.50 | 0.50 | - | 0.40 | 0.35 | 0.50 | 0.85 | 0.40 | 0.55 | 0.50 |
| K | 0.48 | 0.48 | 0.38 | 0.46 | - | 0.28 | 0.54 | 0.64 | 1.08 | 0.26 | 0.48 | 0.44 |
| Cl- | 0.38 | 0.36 | 0.37 | 0.37 | - | 0.30 | 0.22 | 0.48 | 0.60 | 0.35 | 0.42 | 0.39 |
| $SO_4$ | 12.12 | 12.82 | 9.82 | 8.18 | - | 7.38 | 4.89 | 18.39 | 35.01 | 8.13 | - | 7.95 |
| Fe | 0.015 | 0.010 | 0.005 | 0.040 | - | 0.115 | 0.165 | 0.050 | 0.055 | 0.045 | 0.030 | 0.090 |
| Mn | 0.007 | 0.043 | 0.007 | 0.008 | - | 0.030 | 0.012 | 0.007 | 0.008 | 0.007 | 0.017 | 0.022 |
| DOC | 2.7 | 3.7 | 2.4 | 3.6 | - | 3.1 | 9.8 | 4.8 | 9.4 | 3.1 | 2.3 | 2.8 |
| Silicates | 2.77 | 2.71 | 2.09 | 0.92 | - | 0.45 | 0.54 | 2.64 | 4.10 | 0.61 | 0.68 | 0.76 |

Note: All parameters in mg/L except pH, TIP (mg $L^{-1}$ as $CaCO_3$), Colour (hazen units), Conductivity ($\mu S/cm^{-1}$)

flow rates probably minimize contact with the marble component of the watersheds. The sodium and chloride values were low in both sample periods.

Sulphate was higher in the fall sampling, and in particular in the subwatersheds of #8 and #9 which had fall values of 18.4 and 35.0 mg/L respectively. The maximum iron value was found in stream #7 which may be a result of mobilization in the many wetlands and bogs of this watershed. The maximum silicate value was found in streams #8 and #9 in both the spring and the fall.

## 5. Sherborne Lake

The Sherborne Lake inflows (Table 13) pH values range from 4.78 to 6.51, with the majority of streams having a pH of less than 5.5. Sherborne stream #9 had the highest pH in the fall sampling. Sherborne stream #9 also has the only minor till plain found in the Sherborne watershed. Nearly all the Sherborne streams had alkalinities of less than 1.0 mg/L (as $CaCO_3$).

The Sherborne streams had low colour values in both spring and fall samplings with no colour value greater than 56 hazen units.

The lack of peat bogs in any subwatershed results in the clarity of the Sherborne Lake streamwaters. The conductivity of the Sherborne streams was lower in the spring than in the fall. The influx of dilute snowmelt waters into the surface water system was a probable cause of the lower conductivity values in the spring sampling.

The fall calcium values were significantly higher than the corresponding spring values in all Sherborne streams. The magnesium values were also higher in the fall than the spring and to a lesser extent sodium and potassium levels indicated a similar trend.

The Sherborne stream sulphate levels were higher in the fall than the spring sampling as were the iron manganese, dissolved organic carbon, and silicate.

Table 13: Chemistry of Sherborne Lake inflows and outflow

| Chemical Parameter | Inflows 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Outflow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **May 1983** | | | | | | | | | | | | | | | |
| pH | 4.91 | - | 5.46 | 5.06 | - | 5.37 | 5.41 | 5.09 | - | 5.00 | - | 5.07 | 5.54 | - | 5.95 |
| Alkalinity | -.44 | - | 0.36 | -.28 | - | 0.27 | 0.59 | -.27 | - | -.28 | - | -.24 | 0.35 | - | 0.96 |
| Colour | 41 | - | 23 | 21 | - | 52 | 49 | 35 | - | 28 | - | 8 | 5 | - | 12 |
| Cond | 29 | - | 25 | 25 | - | 22 | 28 | 27 | - | 62 | - | 28 | 29 | - | 27 |
| Ca | 2.1 | - | 2.2 | 2.0 | - | 2.1 | 2.4 | 2.3 | - | 2.2 | - | 2.4 | 2.7 | - | 2.4 |
| Mg | 0.56 | - | 0.48 | 0.44 | - | 0.44 | 0.62 | 0.54 | - | 0.52 | - | 0.42 | 0.42 | - | 0.52 |
| Na | 0.50 | - | 0.50 | 0.50 | - | 0.50 | 0.50 | 0.50 | - | 0.55 | - | 0.50 | 0.60 | - | 0.60 |
| K | 0.34 | - | 0.24 | 0.18 | - | 0.18 | 0.46 | 0.38 | - | 0.62 | - | 0.46 | 0.48 | - | 0.38 |
| Cl- | 0.11 | - | 0.25 | 0.20 | - | 0.13 | 0.18 | 0.18 | - | 0.12 | - | 0.25 | 0.30 | - | 0.38 |
| $SO_4$ | 7.50 | - | 6.40 | 7.10 | - | 5.32 | 7.77 | 7.66 | - | 7.42 | - | 8.01 | 8.55 | - | 7.34 |
| Fe | 0.08 | - | 0.04 | 0.075 | - | 0.32 | 0.715 | 0.085 | - | 0.07 | - | 0.01 | 0.01 | - | 0.02 |
| Mn | 0.061 | - | 0.018 | 0.046 | - | 0.038 | 0.065 | 0.050 | - | 0.070 | - | 0.050 | 0.007 | - | 0.006 |
| DOC | 5.1 | - | 5.1 | 3.4 | - | 3.3 | 4.9 | 4.1 | - | 6.1 | - | 3.2 | 2.0 | - | 2.3 |
| Silicates | 1.25 | - | 0.83 | 0.90 | - | 0.48 | 0.64 | 0.73 | - | 0.68 | - | 2.09 | 1.79 | - | 1.24 |
| **Nov 1983** | | | | | | | | | | | | | | | |
| pH | 4.89 | 4.82 | 5.46 | 5.27 | 5.61 | 5.02 | 5.32 | 5.57 | 6.51 | 5.06 | 6.03 | 4.78 | 5.34 | 4.79 | 6.08 |
| Alkalinity | -.42 | -.29 | 0.39 | 0.16 | 0.42 | -.12 | 0.41 | 0.74 | 7.17 | -.19 | 0.99 | 0.59 | 0.53 | -.52 | 1.32 |
| Colour | 28 | 13 | 20 | 27 | 4 | 50 | 55 | 8 | 56 | 23 | 26 | 27 | 7 | 45 | 13 |
| Cond | 40 | 39 | 29 | 37 | 29 | 43 | 37 | 51 | 51 | 43 | 28 | 37 | 32 | 54 | 27 |
| Ca | 5.1 | 3.3 | 3.5 | 2.5 | 4.4 | 3.1 | 4.9 | 5.1 | 3.9 | 2.7 | 5.3 | 3.1 | 2.4 | 2.4 | 2.2 |
| Mg | 1.36 | 0.84 | 0.88 | 0.58 | 0.88 | 0.90 | 1.00 | 1.34 | 1.00 | 0.70 | 1.30 | 0.78 | 0.56 | 0.62 | 0.52 |
| Na | 0.70 | 0.55 | 0.55 | 0.45 | 0.60 | 0.55 | 0.70 | 1.20 | 0.55 | 0.55 | 0.60 | 0.50 | 0.50 | 0.50 | 0.50 |
| K | 0.26 | 0.16 | 0.10 | 0.16 | 0.12 | 0.50 | 0.78 | 0.78 | 0.32 | 0.16 | 0.66 | 0.12 | 0.18 | 0.44 | 0.32 |
| Cl- | 0.84 | 0.77 | 0.59 | 0.38 | 0.55 | 0.51 | 0.47 | 0.71 | 0.49 | 0.60 | 0.67 | 0.44 | 0.45 | 0.42 | 0.37 |
| $SO_4$ | 17.44 | 11.39 | 10.58 | 8.81 | 12.72 | 10.66 | 16.19 | 13.48 | 13.48 | 9.32 | 18.03 | 11.52 | 8.51 | 7.71 | 7.52 |
| Fe | 0.090 | 0.045 | 0.185 | 0.070 | 0.165 | 0.205 | 0.020 | 0.085 | 0.080 | 0.010 | 0.125 | 0.255 | 0.015 | 0.120 | 0.085 |
| Mn | 0.116 | 0.072 | 0.035 | 0.032 | 0.079 | 0.062 | 0.012 | 0.008 | 0.088 | 0.012 | 0.121 | 0.062 | 0.006 | 0.016 | 0.037 |
| DOC | 7.2 | 4.6 | 8.1 | 3.8 | 6.5 | 6.6 | 2.6 | 6.5 | 4.9 | 2.5 | 7.9 | 5.2 | 2.2 | 4.7 | 2.9 |
| Silicates | 3.74 | 3.13 | 2.79 | 1.08 | 2.00 | 2.34 | 3.55 | 4.27 | 1.70 | 2.91 | 3.43 | 2.19 | 1.19 | 1.12 | 0.69 |

Note: All parameters in mg/L except pH, TIP (mg $L^{-1}$ as $CaCO_3$), Colour (hazen units), Conductivity ($\mu S/cm^{-1}$)

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Appendix 1: Surficial Geology Descriptions

Table 14: Identification Criteria for Glacial Till Types

| Surficial Geology Map Unit | Air Photo Evidence | Field Criteria |
|---|---|---|
| 1. Exposed Bedrock | - white glare<br>- jointing or gneissosity trends apparent<br>- sparsely treed<br>- vegetation - moss & pine | - exposed bedrock<br>- samll pockets of till or vegetative debris<br>- weathered bedrock<br>- a few large erractics present<br>- often ridge or cliff areas |
| 2. Thin Till and Rock Ridges | - mottled appearance due to coniferous deciduous mixture<br>- minor fault visible<br>- associated with steeper slopes<br>- vegetation - yellow birch, poplar, pine, hemlock | - deposit >1 m thick average .5 m thick<br>- unsorted material<br>- erratics present<br>- numerous rock ridges present<br>- pit & mound topography<br>- A, B horizons developed C often absent |
| 2A. Continuous Thin Till | - mottled but deciduous dominates over coniferous<br>- minor faults partially visible<br>- associated with gentle slopes, thin till and rock ridges areas<br>- vegetation - yellow birch, poplar, prine, some maple, oak and hemlock | - deposit >1 m thick average .5 to 1m thick<br>- unsorted material<br>- infrequent rock ridges outcrop<br>- pit & mound topography occasionally<br>- A, B & partial C horizon development |
| 3. Minor Till | - light in colour, smooth continuous<br>- minor faults & lineaments absent<br>- vegetation - maple, beech ironwood | - deposit 1 m thick<br>- unsorted material<br>- erratics<br>- continuous till cover<br>- gently sloping topography |

Table 15: Identification Criteria for Glacial-Fluvial Ice Contact and Alluvium

| Surficial Geology Map Unit | Air photo Evidence | Field Criteria |
|---|---|---|
| 4. Kame | - moderate in colour<br>- bedrock faults not visible<br>- "kettles or port holes" present<br>- rolling surface<br>- vegetation - maple, oak | - deposit >2 m thick<br>- unsorted to moderately sorted<br>- no erratics present<br>- slumping<br>- deformation of beds |
| 5. Outwash | - dark colour near water<br>- level plain, terraces possible<br>- vegetation - maple, beech, white pine and white birch<br>- meandering streams | - deposit >2 m thick<br>- moderately sorted sand and gravel<br>- cross bedding evident<br>- no erratic present<br>- A, B & C soil horizons present |
| 6. Sand-Plain/ Beach | - dark colour<br>- level<br>- raised above local water table<br>- vegetation - white pine, hemlock and some spruce<br>- meandering streams | - well sorted sand deposit<br>- A, B, C, soil and horizon present<br>- level<br>- no erratics present |
| 7. Alluvium | - light in colour<br>- level<br>- vegetation - rushes, reeds, alders, some hemlock and balsam near edges | - deposit 1-2 m thick<br>- cross bedding evident<br>- no erratics present<br>- present only proximal to largest streams |

Table 16: Identification Criteria for Peat Types

| Surficial Geology Map Unit | Air photo Evidence | Field Criteria |
|---|---|---|
| 8. Peat | - dark colour<br>- level plain gneissosity<br>- puffy or spiked appearance<br>- vegetation - hemlock, balsam, black spruce and sphagnum | - highly organic soil<br>- level, no rock ridges<br>- no soil profile<br>- no erratics<br>- generally thin over bedrock<br>- large peat areas<br>- generally overlying sand |
| 8A. Peat | - light in colour<br>- level plain<br>- puffy or spiked appear-ance near edges<br>- vegetation - rushes, reeds and alderssteeper<br>- meandering streams | - highly organic soil<br>- level no rock ridges<br>- no soil profile<br>- no erratics<br>- generally overlying and<br>- flooded in spring<br>- adjacent to large water body |
| 8B. Peat-Submerged | - dark or lighteciduous<br>- extension of water body | - submerged - less than 1 m water<br>- alders, reeds and rushes<br>- no conifers |

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